MIT's Magazine of Innovation

# Technology Review

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# Tech+Finance 2005





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# Contents

Volume 108, Number 3



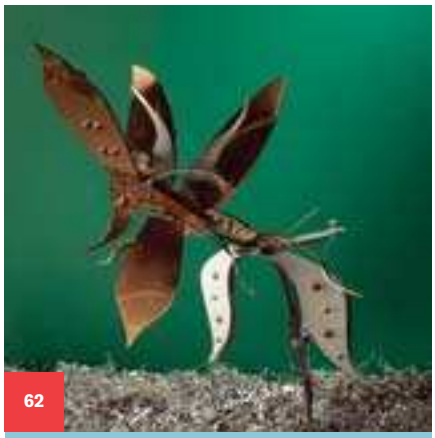
## Tech and Finance 2005

There is no better way to get a feel for the future of emerging technologies than by looking at what is getting funding—and what isn't. Though the private and public markets are once again bullish on certain technologies, federal funding for nondefense R&D is in decline, and that has many worried. A team of *Technology Review* editors finds hope, but also danger, for tech financing.




Cover photo illustration, Joe Zeff; cover photo, Veer

# Contents



62

**DEMO**
**Interesting Interfaces**
The newest from MIT's Media Lab.

31

**BRIEFCASE**
**Genetic Savings and Clone**
The company that clones pets.

68

**MEGASCOPE**
**Kalashnikov's Gun**
What a deadly example of good design can tell us about innovation.



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The *Technology Review* Index, which has been developed by the editors of *Technology Review* in conjunction with Standard and Poor's, includes the *TR* Large-Cap 100 and its sibling, the *TR* Small-Cap 50. These two indices will track both the most powerful innovators and the up-and-comers in the 10 most innovative industries in the global economy.

Every month, the magazine will contain a page that discusses the performance of the indices, their constituent industries, and any of their component stocks that stand out in particular.

But the indices themselves will live and breathe online, where they will be updated daily. What's more, our site will use the indices as the reference point of an ongoing discussion about the people, companies, technologies, and financial rumblings that make a difference to anyone invested in the world of emerging technologies.


**About Technology Review** *Technology Review*, the oldest technology magazine in the world, is published by Technology Review, Inc., an independent media company owned by the Massachusetts Institute of Technology. Founded in 1899, *Technology Review* describes emerging technologies and analyzes their commercial, economic, social, and political impact for an audience of senior executives, researchers, financiers, and policymakers, as well as for the MIT alumni. In addition, Technology Review, Inc. produces technologyreview.com, a website that offers daily news and opinion on emerging technologies. It also produces live events such as the Emerging Technologies Conference. The views expressed in *Technology Review* are not necessarily those of MIT.

# Index

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One Main Street, 7th Floor,
Cambridge MA 02142
Tel 617-475-8000
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Publishing consultants: CCI/Crosby
A Division of Connell Communications, Inc.

# The Crisis in Tech Finance

Finance pays for new technologies, but financiers and technologists are sometimes at odds.

Financiers are by their nature conservative and analytical: they speculate on the future performance of markets, but the whole of their art is to make speculation as predictable as human affairs allow. By contrast, technologists are ambitious and optimistic: their innovations are applied science or engineering, but they believe their inventions will dominate markets or create entirely new businesses. Much of the business of technology finance consists of the wooing of wised-up financiers by ardent technologists.

But there is this paradox: while financiers are jaded, when they fall for something, they fall hard. They lose all their natural caution. I was the editor of the technology business magazine *Red Herring* during the Internet boom, and if it is now received wisdom that the venture capitalists and investment bankers who funded that mania were the cynical promoters of a financial euphoria, I never saw it. Financiers loved the boom more than most dot-com chief executives. But like disappointed lovers, financiers were bitter when their speculations proved unfounded, and without income or more capital, many of the companies that *Red Herring* wrote about were, in the end, ruined.

The long winter of technology finance followed. After Internet and communications company stocks collapsed in mid-2000, the market for initial public offerings of *all* technology companies closed, too—and without an "exit strategy," venture capitalists couldn't, or wouldn't, invest in startups.

It's been a long four and a half years. But 2004 seemed a kind of reflorescence for technology finance. Google's wondrous IPO in August excited investors, but Google was the least of it. Two hundred thirty-three technology companies went public on U.S. exchanges in 2004, raising $43 billion, compared to 2003, when 79 companies went public, raising just $16 billion.

So why am I not happier? Because financiers are still bilious from the boom: they remain disinclined to invest in emerging technologies. As we describe in this month's special report, "Tech and Finance 2005" *(see p. 35)*, total venture capital investments in the United States in 2004 were up 8 percent over 2003. That is all to the good. But worryingly, while the valuations for later-stage startups increased in 2004, money for younger startups did not. Venture capitalists are funding proven technologies at established startup companies, especially those whose work is relevant to Internet security, national security, and biodefense.

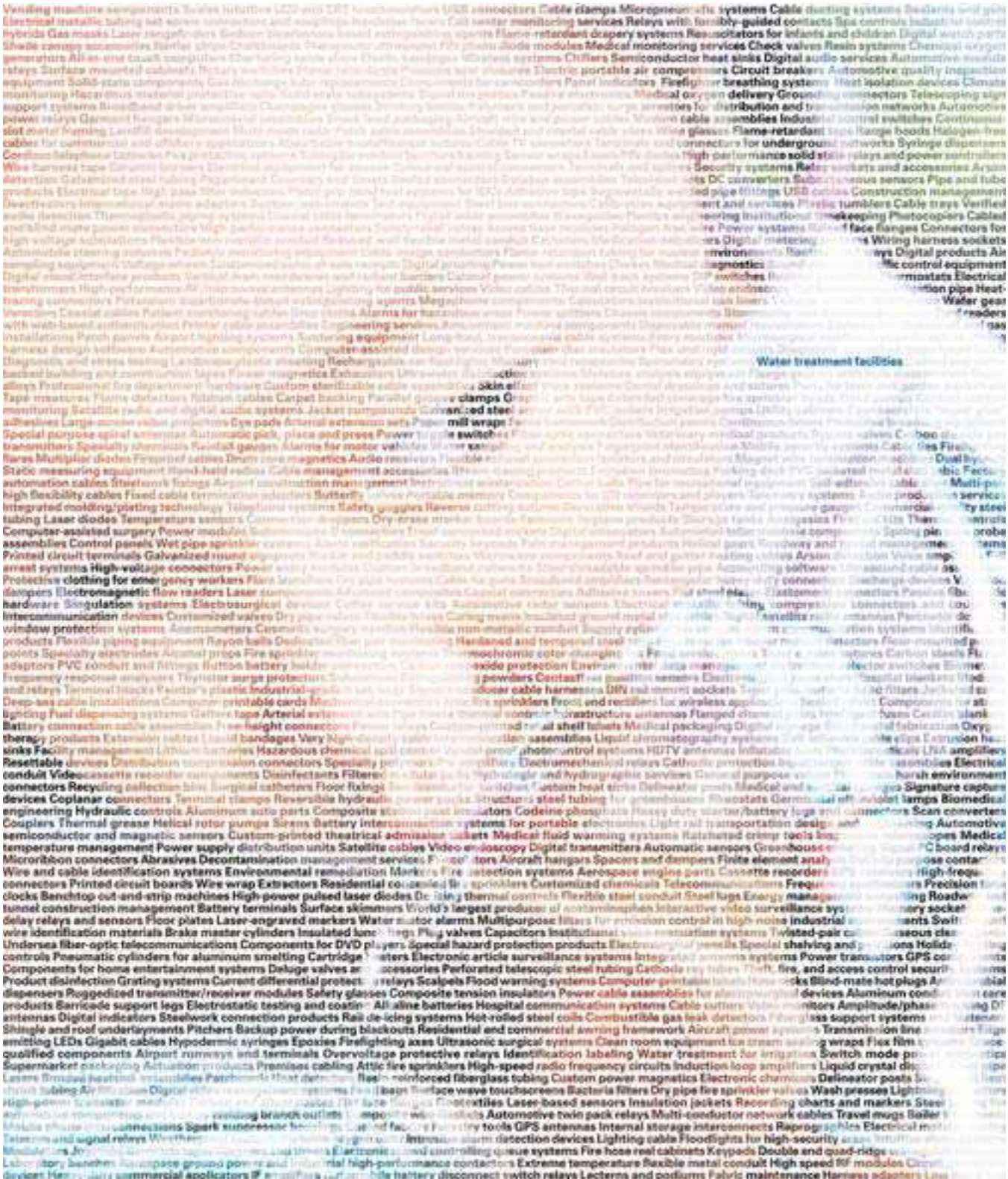
All of this would matter less if public companies were investing in emerging technologies. They are not. Over the last four years, corporations have spent less and less on basic research and development. Worse, the U.S. government is investing less in new technologies, too. In the 2005 federal budget, R&D spending has increased 4.8 percent to $132.2 billion, but 80 percent of that increase went to defense research—and most of that to new weapons systems like ballistic-missile defense. This meant cuts elsewhere: the National Science Foundation, for instance, saw its R&D budget decrease by .3 percent to $4.1 billion in 2005. Even the National Institutes of Health, long a favorite object of federal largesse, enjoyed an R&D budget increase of only 1.8 percent, to $27.5 billion—below the rate of inflation.

Distraught technologists might seem only to be saying, Can I have more money, please?—were it not for one thing. The drought of venture capital for early-stage startups, the indifference of public companies to basic R&D, and the emphasis on security by the government have conspired to create what our report calls an "innovation vacuum."

Why am I not happier? Because financiers are still bilious from the boom: they remain disinclined to invest in emerging technologies.

The crisis can best be understood as an exaggerated example of what economists like to call the "transfer gap"—that is, the failure of emerging technologies that have been "pushed" (to use economic jargon) into research by technologists to be "pulled" into commercial development by financiers. The transfer gap occurs when financiers demand more certainty about the future prospects of a given technology than technologists can supply. When financiers feel very cautious, as they do right now, the gap gapes wide.

One solution proposed by Michael Kremer, the Gates Professor of Developing Societies at Harvard University, is for governments to bridge the transfer gap by making "purchase commitments" for the successful development of socially desirable technologies. The idea is pretty; it creates demand that startups can satisfy without asking governments to make choices better left to the markets. Certain of demand, financiers would be ready to back risky ventures. Kremer suggests using purchase commitments to create therapies for infectious diseases for the poor world. Defense spending is a kind of purchase commitment. Might it work for other technologies, too? Write to me at jason.pontin@technologyreview.com. ■

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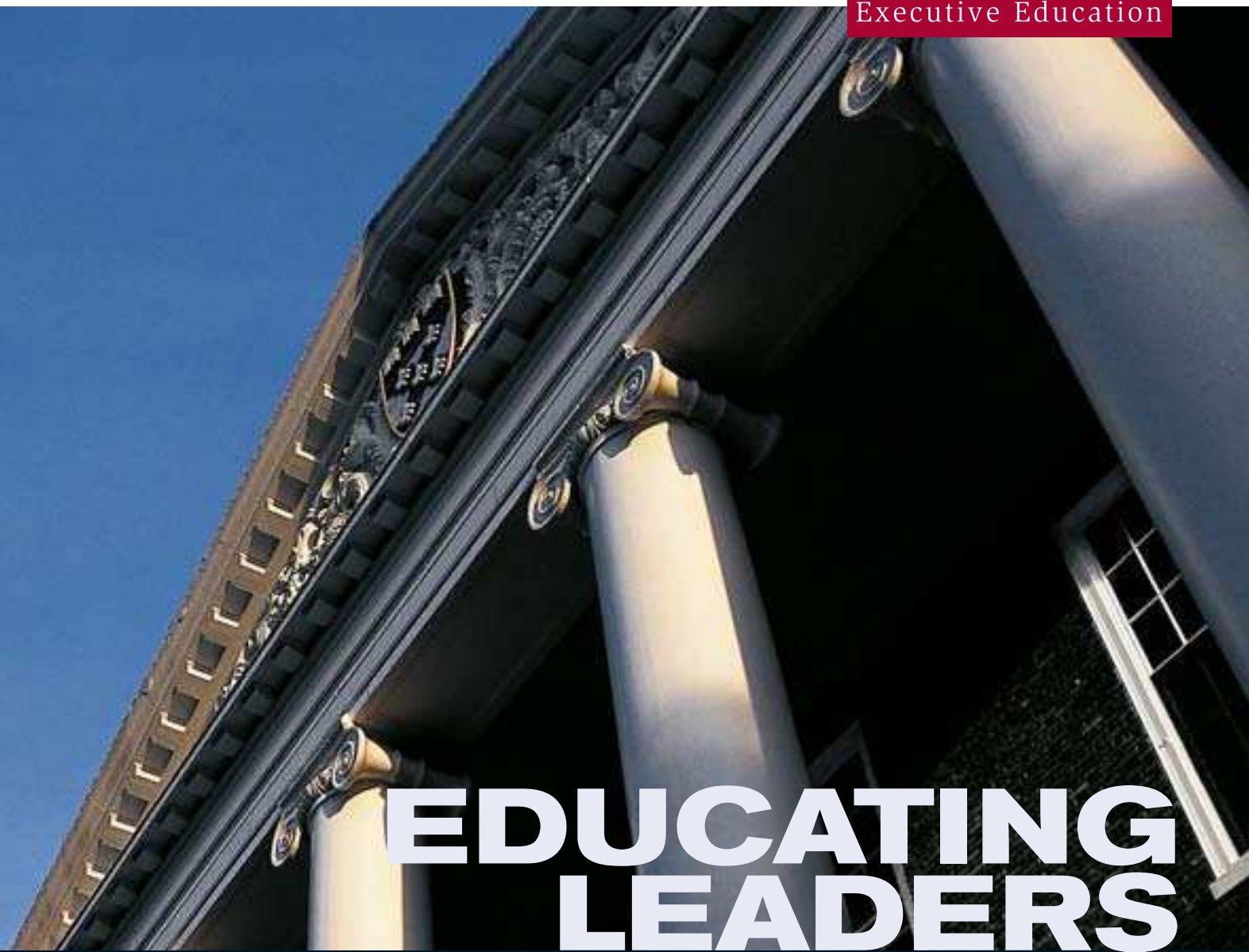

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# Letters

### WHAT'S NEXT FOR GOOGLE?

Charles Ferguson draws parallels between Google and Microsoft's past rivals, predicting an edge for Microsoft ("What's Next for Google," January 2005). But Google is unlike any company Microsoft has witnessed in the past in how it identifies opportunities, innovates, operates, and pursues growth. Even if Microsoft is to develop superior search, it will find it impossible to get users to abandon their much-loved search engine. To survive Google, Microsoft has only one option: to out-innovate it. But Microsoft's past performance in innovation doesn't hold much promise of that happening. Innovation is something that simply cannot be bought. It has to be systemic—which is why in this game, it's advantage, Google.

**Manu Sharma**
New Delhi, India

Interesting times are facing Google. Like browsers were in 1995, search is now the killer technology in the evolution of the Web. It has produced opportunities for financial windfalls unprecedented in business and technology. But unlike companies that fought the browser war of the mid-1990s, Google has been insightful and preëmptive in the way that it has crafted its next evolution. While it has become the preëminent destination for finding information on the Web, this represents only a stepping-stone for the company. Enabling users to interact with data important to them on every level is where Google may ultimately change the world. This is exactly what Microsoft's been trying to achieve for the last decade, but hasn't. Google's war won't be about search. It'll be about us and what we want to do, not just where we want to go.

**Jason Wiener**
Founder, Dipsie
Chicago, IL

By deciding what we see first, search engines have an enormous impact on our perception of reality, and I don't think that humanity will embrace a single technology defining that reality. Moreover, being able to index ever larger volumes of data becomes meaningless when the industry takes a one-size-fits-all approach. What is needed are cyber-agents that discern who you are and what you are interested in, and respond with personalized results.

**Liesl Capper**
CEO, Mooter
Sydney, Australia

I see what your are getting at with your January cover, but you did it in a tasteless and sacrilegious way. There is only one God, and he doesn't run Google—not directly, anyway.

**Richard Simpson**
Beavercreek, OH

### KILLING SCIENCE AT NASA

Mark Williams misunderstands the changes at NASA ("Toward a New Vision of Manned Spaceflight," January 2005). NASA has for many years had long-term plans for manned spaceflight and manned trips to Mars—that is not something introduced by President Bush. What's new is that the Bush administration is giving manned spaceflight priority at the expense of ongoing and future scientific programs. By deëmphasizing science, the administration may destroy NASA's most important activity.

**David W. Hogg**
New York, NY

### ABOUT HAPPINESS

James Surowiecki's article ("Technology and Happiness," January 2005) suffers from a one-sided paradigm. The question considered was whether technology in general or technological change in particular causes happiness to increase, decrease, or remain the same. But technology might be better understood less as a cause of happiness than as an effect of it. Technological change, after all, is clearly the product of human action, which in turn is generally undertaken in the pursuit of happiness. As such, the pursuit of happiness might be considered to be the cause of technological change.

**Harvey Hartman**
Santa Cruz, CA

### TR'S NEW LOOK

Your new design is clean and distinctive, the navigational cues allow me to focus on the content, and the articles are topical and well-written. Kudos!

**Chris Stephenson**
Boston, MA

How pleased I am to read of your plans to take *Technology Review* in a new direction. For the last several years, *TR* has been full of breathless, uncritical claims of the newest and the greatest things that were supposedly just around the corner. I encourage you to choose investigative, critical, and mature writers who will distinguish passing fads from real advances.

**Anthony Lunn**
Princeton, NJ

I'm thrilled with what you've done. The January issue includes excellent writers, and the range of topics reflects the talents and interests of the MIT community.

**Robert Shumsky**
Rochester, NY

You seem to have almost abandoned technology and shifted to editorial commentary about technology. The greatest sin in journalism, especially scientific journalism, is pontification.

**Norman Moore**
Boca Raton, FL

**CORRECTION:** In "Microsoft Declares War on Spam" (February 2005), we misrepresented a Pew Internet and American Life Project survey as stating that "60 million people said they had ordered products or services advertised via unsolicited e-mail." The correct figure is six million people.

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### HOW TO CONTACT US

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Each readme is an executive summary of a fatter story in the magazine, stripped to its logical bones. Each concludes with a call to action.

FINANCE

# Research Funding: Get Worried


Funding for science and technology research in the United States is in trouble. For years, spending by the federal government, particularly through the National Science Foundation (NSF) and the National Institutes of Health (NIH), has been critical to supporting the basic research that often leads to innovative technologies and the startup of innovative companies. But as our special report "Follow the Money" *(p. 35)* explains, sharp cutbacks in the 2005 federal budget for non-defense-related research is creating an inhospitable climate for the emergence of new technologies.

One of the most troubling aspects of this crisis in federal funding is that it has gained so little attention from the general public and from the financial community, which has long benefited from federally supported R&D. Leading figures in the U.S. research community, such as Shirley Ann Jackson, president of the Rensselaer Polytechnic Institute and 2004 president of the American Association for the Advancement of Science, have been vocal and energetic in warning about basic research's funding woes. But it seems that few outside the university research community are listening, or care.

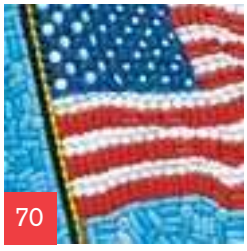
Current cuts in basic-research support could not, in many ways, come at a worse time. As Jackson points out in our special report, while defense R&D received large increases in the 2005 federal budget, basic research across a broad front is also vital to our national security. For example, the missile defense program, which many scientists think has little chance of success, received one of the largest spending increases in 2005, a 15.8 percent jump to $8.8 billion. But surely it's worth asking how Congress and the administration expect any ambitious technology program, including missile defense, to succeed without the fundamental research in physics and engineering necessary to support it.

Those who invest in emerging technologies should be particularly worried. The opportunities in the private and public equity markets are looking increasingly attractive. Google's initial public offering was just one of many successful tech IPOs in 2004. And venture capitalists are beginning to invest again in technology startups. All that should bode well for the future of technology financing. But where will the next generation of innovative technologies come from? No one should forget that the search technology behind Google was developed by Sergey Brin and Larry Page as part of an NSF-funded Stanford University digital-library project.

It's time for those who make their livings by investing in emerging-technology companies to voice concern. Rational voices in the university research community, like Jackson's, won't be heard unless financial leaders amplify the message.

The next few months will be crucial, as President Bush's proposed 2006 federal budget is debated in Congress. While the na-

tion's enormous deficit will certainly mean greater frugality, legislators need to strengthen, even if only modestly, funding for NSF and NIH. A good starting point would be to hold President Bush and Congress accountable for reneging on 2002 legislation that authorized a doubling of NSF's budget by 2007. That doubling won't happen now: that's clear. But financial leaders who are dependent, one way or another, on government funding of research should ask why not. There should be outrage over the erosion of U.S. research institutions. ■




REGULATION

## Dear FDA: Get Well Soon

What's wrong with the regulatory agency and how to cure it.

Last December, the U.S. Food and Drug Administration warned doctors that a drug widely prescribed to children for attention deficit hyperactivity disorder carried with it "the potential for severe liver injury." The FDA demanded that the manufacturer, Eli Lilly, relabel the product with a new bold-letter warning. Since the drug was introduced in 2002, some two million people have taken it. The FDA discovered that two of these patients had suffered subsequent liver problems.

So far, so good. Perhaps a little overzealous. But the FDA had been less vigilant about more serious safety concerns related to the pain relievers Vioxx, Bextra, and Celebrex. An FDA whistleblower told the U.S. Congress that tens of thousands of patients may have died needlessly because of the FDA's misjudgments about Vioxx alone. Perhaps the whistleblower overstated the influence of drug manufacturers on the FDA's hesitation to warn the public about these drugs. Nevertheless, a thorough examination is in order.

As Stephan Herrera explains in a review of Philip J. Hilts's book *Protecting America's Health: The FDA, Business, and One Hundred Years of Regulation*, there is talk in Washington of overhauling the FDA to ensure that such mistakes don't recur *(see "Who Needs the FDA?" p. 70)*. Some are asking for the creation of an independent product-safety review board to oversee the FDA's own product-safety review board. The FDA itself has asked the National Academies' Institute of Medicine to conduct a review and vows to act on its recommendations.

In this rush to review and restructure the agency, the root cause of all that ails the FDA is being overlooked. The FDA needs more money.

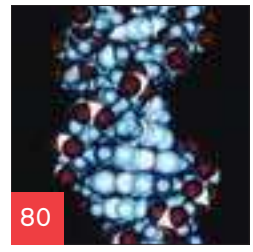
Other critics, particularly those on the right who are ideologically antagonistic to all regulation, argue the agency must be destroyed altogether. They say it is a kind of tyranny to tell sick citizens they cannot use risky therapies, so long as the risks are clearly explained. They believe a U.S. drugs agency should limit itself to describing the efficacy of medicines.

In this rush to review and restructure the agency, the root cause of all that ails the FDA is being overlooked. Despite being responsible for the health and well-being of 300 million Americans—and the proper working order of close to $1.5 trillion worth of products and services—the agency must make do with an annual budget of $1.5 billion. No other government agency is required to do so much with so little. The FDA needs more money and more guidance in how to spend it for the greater good. It won't be easy for a Republican-dominated Congress to give the FDA more money and power, but the public and media will surely back those who lead the charge.

If something must be scrapped, let it be the "user fee" system. Hundreds of millions of dollars in product-review fees paid by drug companies go to the FDA. Congress and the FDA will say that they can't afford to ditch the user fee system, but it creates intolerable conflicts of interest.

Failing all of this, surely the FDA at least deserves a real commissioner. We recommend the White House look at Stanford University's president emeritus, Donald Kennedy. Now the editor in chief of *Science*, Kennedy served as FDA commissioner from 1977 to 1979. There is some precedent for rehiring commissioners. Kennedy is wiser now and even more highly regarded by scientists and the biopharmaceutical industry. Another good choice would be David Kessler, dean of the University of California, San Francisco, School of Medicine, who was an effective and powerful commissioner of the FDA under both President George H. W. Bush and President Bill Clinton. The FDA again needs this type of expertise and strong leadership.

With the proper remedy and the right physician, the FDA can be healed. ■




BIOTECHNOLOGY

## Fund a "Moonshot" for RNAi

Translating promising science into new therapies.

Amid the national debate over stem cells and therapeutic cloning, there's another biomedical technology that is showing increasing promise without the ethical conundrums. RNA interference (RNAi) is a natural regulatory process in which small, double-stranded RNA molecules turn off specific genes in a cell. Because RNAi is highly targeted and efficient, it has become a widely used tool for understanding what genes do and how they work. But its real payoff lies in new therapies—and developing them will require a renewed commitment to funding and research.

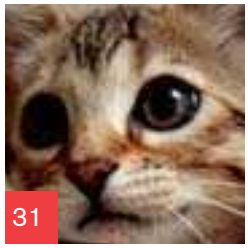
Exploiting the properties of RNA molecules could yield more-effective drugs to fight cancer, HIV, influenza, and other diseases. Rather than blocking the effects of specific proteins, which is what conventional drugs do, an RNAi-based therapy could in theory stop the proteins from being made in the first place. Mark

Kay, director of the Program in Human Gene Therapy at the Stanford University School of Medicine, calls RNAi "incredibly robust technology with incredible therapeutic potential" but cautions that it's in a "very new, very early stage."

Indeed, the main hurdle so far has been the delivery of RNAi therapies in the body: RNA molecules tend to degrade quickly in the bloodstream and are not easily taken up into cells. But as we report in this month's "Synopses" *(see "Cholesterol Cure?" p. 80)*, researchers have now demonstrated that RNAi techniques can lower cholesterol levels in mice. The key advance: chemically modifying synthetic RNA molecules so that they remain potent after being injected into the blood. Major challenges remain to be met before RNA molecules begin to yield drugs, but this is a critical advance and an encouraging, albeit early, indication of the therapeutic potential of this kind of treatment.

In the past few years, the RNAi field has benefited from generous funding and the work of hundreds of scientists in the United States and abroad. RNAi companies such as Alnylam Pharmaceuticals and Benitec are conducting animal tests and moving toward clinical trials. At the National Institutes of Health, there are ongoing discussions about funding multi-institutional RNAi centers to encourage collaborative research.

But that's not enough. We have closely followed the progress of research on RNAi ever since its therapeutic potential became clear *(see "Prescription RNA," December 2002/January 2003)*. It may be early, but the time is right for an international "moonshot" project in which academics, clinicians, and companies collaborate. The National Institutes of Health should weigh the recommendations of its working groups and set aside the funds for an initiative that will yield human testing of RNAi-based therapies within five years. There are different approaches—scientists disagree, for instance, on whether gene therapy techniques (using DNA "vectors") or direct RNA delivery is most promising—so the initiative should support them all. At the same time, scientists and the media should be careful not to exaggerate the propinquity of the technology but rather move forward with cautious, responsible optimism. ■




CLONING

## Let the Market Decide

Some would ban cat cloning—but pet lovers are willing to pay for it.

December's newspapers were dominated by stories about the Scott Peterson verdict, preëlection violence in Iraq, and, of course, the Indian Ocean tsunami. But one event barely made the front pages: Julie, a Dallas-area airline worker who withheld her last name, took ownership of a perfect genetic copy of her deceased cat Nicky. To create Little Nicky, Julie paid $50,000 to Sausalito, CA–based Genetic Savings and Clone (GSC)—which says it will deliver at least four more cat clones to clients this year, and will also create the world's first dog clone *(see "Genetic Savings and Clone: No Pet Project," p. 31)*.

> Why should people be denied copies of beloved but departed dogs or cats merely because their money might be better spent?

Dolly the sheep, the first mammalian clone to survive to adulthood, was born barely eight years ago. But much sooner than most people expected, society has entered the age of consumer-oriented cloning services. Ready or not, citizens must decide whether to resist this latest advance in consumer biotechnology or condone and assimilate it—as they have the once controversial technique of in-vitro fertilization of human embryos.

Already critics have called GSC's clones "Frankenpets," have accused the company's scientists of tampering with nature, and have disparaged its clients as desperate suckers with unhealthy attachments to their lost pets. Who else, they ask, would spend an amount exceeding the median annual income of U.S. households to see poor Fluffy or Fido again?

In GSC's defense, this is not what the company promises. Customers are carefully informed that clones are, in essence, later-born twins and do not carry their genetic donors' memories or "souls."

But it's easy to see where many of the critics' concerns over pet cloning originate. For one thing, other companies have applied biotechnology to pets in undeniably silly ways: witness the GloFish, a transgenic zebra fish engineered by Yorktown Technologies of Austin, TX, to glow florescent red in a dark aquarium. Then there's the fact that cloning technology has yet to be fully perfected: some clones develop abnormally or die prematurely, which understandably disturbs animal-rights activists. But clones with genetic abnormalities will doubtless become less common as the technology improves.

More doggedly, opponents of animal cloning say it's unethical to spend so much money replicating deceased pets when thousands of cats and dogs languish in animal shelters awaiting homes. But while the abandoned-pet problem in the United States is real and shameful, it seems strangely illiberal to propose a ban on pet cloning. Infertile human couples are not criticized for pursuing IVF rather than adoption. Why should someone be forbidden a copy of a beloved but departed cat or dog merely because that money might be better spent? In free societies people often spend money on frivolous things.

Critics of pet cloning sometimes seem to be criticizing free markets as much as technology. Other critics seem really to be worrying about human cloning. But free-market societies have historically adopted a watchful but welcoming attitude toward innovation: if a technology is applied safely and responsibly, and people are willing to pay for it, then we should applaud the entrepreneurs who make it available.

Innovative companies that develop a controversial but valuable technology in a controlled, transparent, and ethical way—as Genetic Savings and Clone shows every sign of doing—should be rewarded, not ridiculed. ■

# Cybercash on Vacation

## What will it take to revive the dream of financial cryptography?

**BACK IN 1996,** a small handful of cryptographers, bankers, and blue-sky thinkers were debating, on Internet mailing lists, the future of money, when one of them came up with a brilliant idea. If they formed an organization, booked a Caribbean hotel in the dead of winter, and put a few papers through the peer review process, they could get their bosses to pay them to hang out in person. They could sit in the sun and dream about what it would take to move cash, settle debts, sell things, sign contracts, and extend credit in the virtual world.

Bob Hettinga, an organizer of the resulting Financial Cryptography Conference, sounds a bit maudlin when he looks back at that first meeting, which took place in February 1997 on the island of Anguilla: "It was like all the net-dot-gods descended on Anguilla. Geeks, financial, cryptographic, and otherwise. Cypherpunks. Bankpunks, pseudonymous individuals, guys who would go on to become senior administration officials, and even people who were paying the $1,000 conference fee in cash because their corporate-sponsored lawyers told them to stay out of the papers after various previous escapades."

This year's conference, taking place in February and March in the Commonwealth of Dominica, doesn't have the same luster. The program is jammed with papers about "privacy-preserving protocols" and "probabilistic escrow" but contains little from the nonacademic world. The people who work at actual financial institutions just aren't as interested in financial cryptography as they were in 1997.



MONIKA AICHELE

It wasn't supposed to be this way. In 1997, the bankers, lawyers, and accountants were fascinated by what the digital magicians could do with a few equations. Even though it's easy to make perfect copies of digital files, for instance, mathematicians found a way to produce a digital $50 bill that would stymie counterfeiters. They didn't stop there. They imagined transactions that avoided the overhead of a central clearing house, digital currency that paid interest, and even complicated digital rights management tools that locked up music, art, and writing with the same equations used to protect money.

Digital currency faces the same problem that credit cards once did, and their acceptance took decades.

Some talked about minting just 500 digital baseball cards for each player and letting the values rise and fall with batting averages. In short, they imagined a world where wealth was not frozen in gold and locked in vaults, but rather held in digital mechanisms that could adapt to whatever people wanted. Some mechanisms could even be as anonymous as paper cash, and transactions wouldn't require much more than the click of a mouse.

But while the mathematics is still fascinating, the emergence of any system based on it is receding into the nebulous future. Today, credit card companies dominate the Web with a system that, at its heart, is little different from the one that employed carbon-paper chits. One of the few companies to find some success in financial cryptography, PayPal, gets most of its revenue from eBay auctions, where it serves, in essence, as a well-designed front end for the credit card system.

Adam Shostack, another of the original organizers, thinks that the reason for the failure of financial cryptography is simple. "People are conservative in how they pay for things," he says. Indeed, the problem for financial cryptography's would-be pioneers is that the old credit card system seems to be good enough for the new online world. If Amazon, Wal-Mart, and other e-commerce sites can keep customers happy with plastic cards, there's little demand for any of the more exciting ideas.

Joseph Nocera, author of *A Piece of the Action*, a history of the credit card industry, says digital currency is facing "a chicken-and-egg question" but points out that credit cards encountered the same problem, and that their acceptance took decades. In fact, 2003 was the first year credit cards and other electronic systems carried more payments than bank checks.

As they come to appreciate just how long the road ahead will likely be, some financial cryptographers are searching for niches where they can flourish in the short term. Take, for example, Waltham, MA-based startup Peppercoin, the brainchild of MIT computer scientists Sylvio Micali and Ron Rivest. Peppercoin is attempting to specialize in very small sums *(see "The Web's New Currency," December 2003)*. One of its bigger initiatives is developing a cryptographic system that would enable people to use their credit cards at parking meters, an application that would be prohibitively expensive for the traditional credit card network, which has a minimum transaction fee of about a quarter. If Peppercoin's technology can cut transaction costs enough, it can capture this market and also make it possible for people to spend small amounts online.

The inability to handle small change isn't the only weakness of the credit card system that calls out for cryptographic innovation. Fraud and identity theft cost society billions of dollars every year. Paul Syverson, a researcher at the U.S. Naval Research Laboratory, believes this leaves the door open for some of the new equations from this year's Financial Cryptography Conference. The privacy-protecting mechanisms imagined by some mathematicians also have the advantage of not relying on identity verification to guarantee transactions. If the flow of money is anonymous, there's no identity to be stolen.

Ultimately, Nocera believes, the high costs and fraud rate in the credit card industry could give new life to the dreams of the original Financial Cryptography Conference. "I actually happen to believe fairly strongly that if someone could ever figure out how to get critical mass for a form of cybercash that is *not* backed by a credit card," he says, "it would be a transformative event for the Web." **PETER WAYNER**

Q&A WITH MIKE LIEBHOLD

## Mapping "Deep Place"

Wireless networks can flesh out the physical world, says Institute for the Future senior researcher Mike Liebhold, author of the white paper "Infrastructure for the New Geography."

**What's the "new geography"?**
We've got huge amounts of data about the planet, but most stays walled off in proprietary databases or people's heads. Wireless networks let us make that information not just visible, but visible in place. It's first-person geography.

**You talk about "deep place."**
Coding data by location gives you an overlay of everything known about a particular spot on the earth. Imagine you can flip open a device, and there's a menu that has cultural information, social information, restaurants. Actuarial information about the probability of a car wreck at this corner. Or maybe just a red light to say that you're in a crime zone.

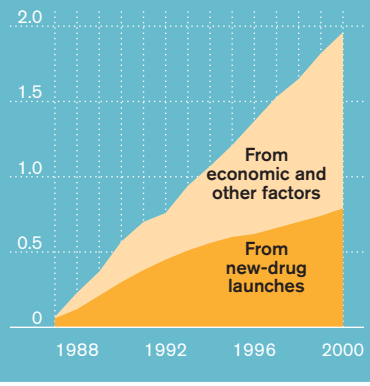
**So how do we get there?**
The Open Geospatial Consortium, the World Wide Web Consortium, and other standards and hacker groups are converging on software mechanisms to bring geodata of all kinds online. But coming up with a user interface for receiving the deep information of place is not trivial. A lot of people have trouble just finding the Pacific Ocean on a map. We can't fix that, but I'd be happy if they could find out a little more about where they are right now. With the World Wide Web, we've built the encyclopedia. Now it's time to do the atlas. **SPENCER REISS**

METRICS

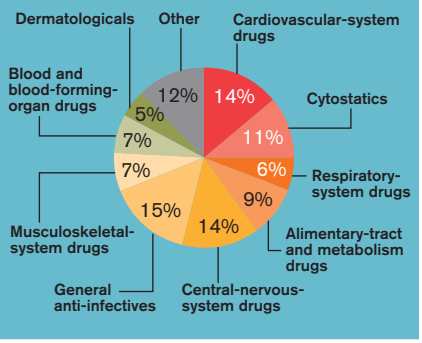
## New Drugs Work

Health economists long thought that advances in medicine have modest effects on life expectancy. But a study of longevity in 52 countries found that new drugs (not including reformulations of drugs already on the market) accounted for 40 percent of the almost two-year increase in average life expectancy between 1986 and 2000. Though circulatory diseases accounted for half of disease-related deaths, drugs targeting the cardiovascular system made up only 14 percent of new drug launches.

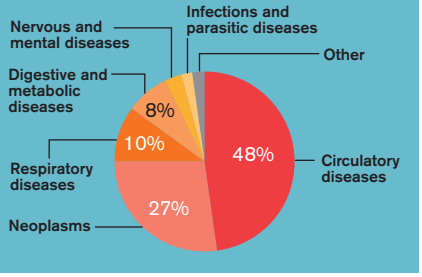
**Cumulative life expectancy increase since 1986 (in years)**




**Types of new drugs launched, 1982-2001**




**Causes of disease-related death, 1982-2001**




SOURCE: NATIONAL BUREAU OF ECONOMIC RESEARCH

FACTS MACHINE

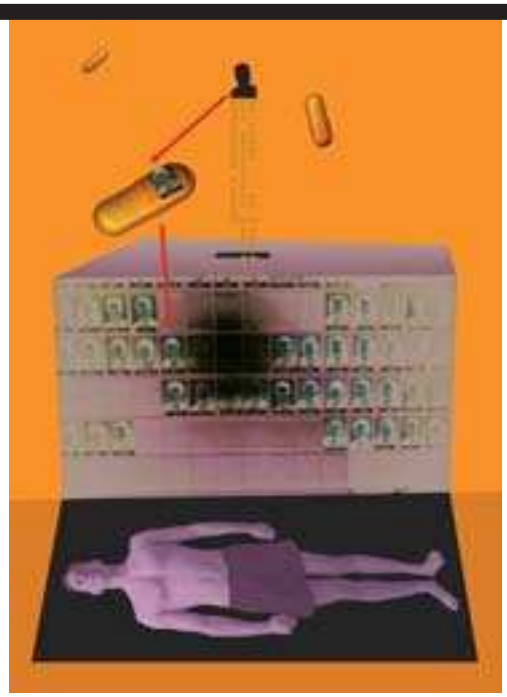
## Cord Blood Makes the Cut

» **5,000 to 6,000 patients** have received transplants of stem cell–rich blood harvested from newborn babies' umbilical cords.
» An estimated **2,000 cord-blood transplants** took place in 2004 alone, with **600** in the United States and **800** in Japan.
» About **two-thirds of cord-blood transplants** treat patients with leukemia. **One-quarter** treat patients suffering from genetic diseases.
» In the United States, more than **40,000 mothers** have donated blood from their newborns' umbilical cords to the National Marrow Donor Program's cord-blood banks. Another **27,000** have donated to the New York Blood Center's National Cord Blood Program.
» Congress appropriated a total of **$20 million** for 2004 and 2005 to subsidize collection and research on cord blood with the aim of creating a bank of **150,000 donors**, enough to provide a match for **80 to 90 percent** of Americans.
» The United States has some **20 private cord-blood banks**, which typically charge **$1,000 to $1,500** to collect the blood and approximately **$100** per year to store it for the exclusive use of the family.
» One such private facility, Cord Blood Registry in San Bruno, CA, reports that it has collected cord-blood samples from some **80,000 clients**.
» In its position paper recommending against commercial cord-blood banking, the American Academy of Pediatrics cites estimates of the chance of a child ever needing to use his stored cord blood that range between **1 in 1,000** and **1 in 200,000**.

SOURCES: NEW ENGLAND JOURNAL OF MEDICINE, NATIONAL MARROW DONOR PROGRAM, NEW YORK BLOOD CENTER, CORD BLOOD REGISTRY, AMERICAN ACADEMY OF PEDIATRICS

PROTOTYPE

## Digital "Clones" Customize Cancer Treatment



If each one of us is biologically unique, why are our ailments so often treated with one-size-fits-all drug regimens? Optimata, an Israeli company based in Ramat Gan, aims to help doctors customize cancer treatments by building a software "clone" of each patient. The company's system starts with a mathematical model that incorporates several hundred equations representing different bodily processes. Doctors then plug in data specific to the patient and his or her disease—the growth rates of the tumor and blood vessels, for example. The software allows the doctor to try out in the digital realm various combinations of drugs and dosing schedules in order to find the treatment regimen that will do the best job of fighting the cancer with the fewest side effects. Researchers are currently testing the system on breast cancer patients at the UK's Nottingham City Hospital. If those trials are successful, Optimata could begin marketing the software as a workstation tool for physicians by 2007. The company is also developing digital treatment-optimization tools for diseases other than cancer.

MONIKA AICHELE

PROFILE

# The Talented Mr. Mitnick

## A notorious hacker turns security guru

BRAD HINES

**FROM HIJACKED PCS** that spew spam to denial-of-service attacks that crash Web servers, cyber-crime means billions of dollars a year in lost revenues and productivity. And no computer user is safe. "It's not if," says Kevin Mitnick, "it's when are you going to get hacked."

Mitnick should know. The former hacker perpetrated a series of high-profile corporate break-ins in the 1990s—and served five years in federal prison for it. Once the FBI's most-wanted cyber-criminal, Mitnick is now one of the world's most sought-after tech security consultants. "A few years back, companies spent more on coffee than on security," he says. Now, they make security their top priority, hiring Mitnick to break into their systems, expose their weaknesses, and teach them how to protect themselves.

Hacking has been Mitnick's priority ever since his teenage years in southern California. First telephone networks, then the Pentagon—then Nokia, Novell, and seemingly every other big company. Today's laws on cyber-crime were practically invented because of Mitnick. His pranks earned him the respect of hackers as well as numerous arrests, culminating in his five-year prison stint. Mitnick spent eight months of that time in solitary confinement, he says, because the judge was told that Mitnick could start a nuclear war by calling up NORAD on a payphone and whistling modem tones into the receiver. His radio was seized for fear that he would turn it into a cell phone. Even using an electric typewriter in the prison library got him handcuffed and whisked away. "These guys were watching too much *MacGyver*," he quips.

That was the turning point in his career. Since his release from prison in 2000, Mitnick has chosen to use his considerable skills to *improve* network security. Now 41 and sporting a decidedly buttoned-down look, Mitnick has made a guest appearance on the TV show *Alias* and earned honorable mentions in many other media outlets. Though he is often recognized as "that hacker guy" in airports and hotels, he says he registers under a fake name only at hacker conventions. But he doesn't give out his private e-mail address or his city of residence; one can't be too careful.

Indeed, the current pace of cyber-crime amazes even Mitnick. Last fall, he and Avantgarde, a tech marketing and design firm in San Francisco, hooked up six computer platforms to the Internet via broadband DSL and recorded the cyber-attacks that occurred over a two-week period. It took less than four minutes for an automated attack to successfully break through the security defenses of one newly connected PC; most machines without an active firewall (a filter that screens suspicious code) faced more than 300 attacks per hour, while those with firewall protection faced fewer than four per hour. But firewalls don't protect against "social engineering," a fancy term for conning users out of such sensitive information as passwords and PINs. The idea that humans are the weak link in any security system was famously exploited by Mitnick in his glory days; he comes across as personable and authoritative, so it's easy to see why people would give him information.

Mitnick's case highlights a point that's increasingly critical as more and more sensitive information and money change hands over the Internet: in his words, "Hacking is a skill set—how you use it is up to your ethics and morals." And the arms race between malicious hackers and security experts will only escalate. "Computer systems are complex," Mitnick says. "There will always be ways to break in." Which means that no matter which side he is on—let's hope it's ours—Mitnick will always be in demand. **GREGORY T. HUANG**

# Engineering Climate

**THE UNITED NATIONS-sponsored Kyoto Protocol, which aims to reduce greenhouse-gas emissions, went into effect in more than 130 countries in February. Nonetheless, climate experts predict that the average global temperature will climb between 1.4°C and 5.8°C during this century. Researchers around the world are working on a wide variety of technologies—from new sources of energy to microbes that could help livestock pass less methane—aimed at mitigating and coping with climate change.**

MARYANN JONES THOMPSON

**COAL:** FutureGen, a U.S.-based collaboration of public and private organizations, is a 10-year, $1-billion effort to build a coal-based, zero-emission hydrogen and electricity plant.

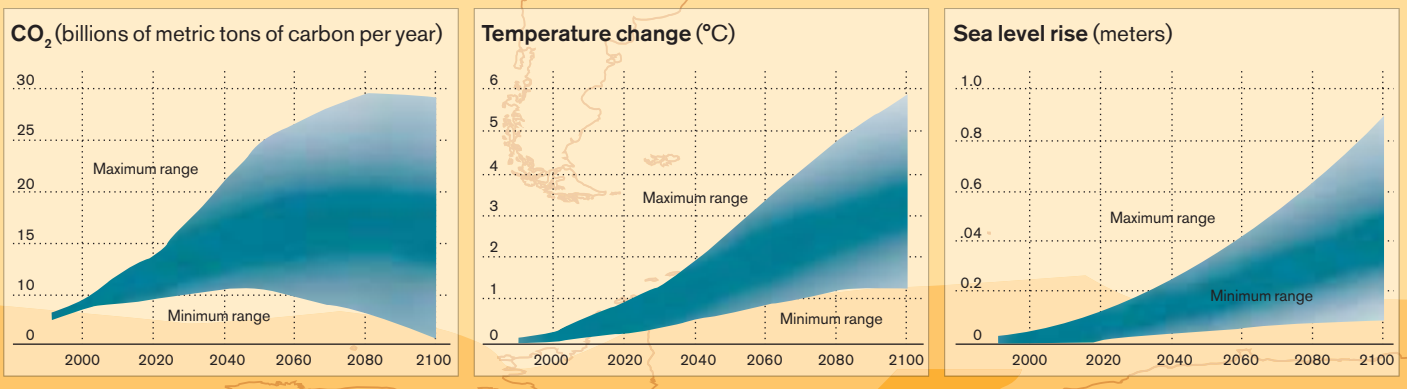
**WIND:** Germany generates one-third of the world's wind-powered electricity and plans to approximately triple its capacity by 2030.

**CARBON SEQUESTRATION:** The J. Craig Venter Institute is analyzing water samples from the Sargasso Sea, employing the same high-throughput sequencing technologies used to sequence the human genome. The institute has discovered 1,800 new species of microbes and over 1.2 million new genes. The U.S. Department of Energy hopes such studies will enable scientists to find organisms and biochemical pathways that could be used to pull excess carbon out of the atmosphere and to provide clean sources of energy.

**RENEWABLES:** Costa Rica derives 92 percent of its energy from renewable sources.

**BIODIESEL:** Brazilian gas stations are now permitted to add 2 percent "biodiesel," a cleaner-burning diesel derived from vegetable oils, to diesel made from petroleum. The government has authorized stations to increase the proportion of vegetable diesel in diesel fuel to 5 percent or more by 2010.

**As worldwide greenhouse-gas emissions climb, so will global temperature and sea level.**




NOTE: TEMPERATURE MAPS ARE BASED ON THE INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE'S "B2" SCENARIO, A RELATIVELY CONSERVATIVE SCENARIO BASED UPON CONTINUED POPULATION GROWTH, INTERMEDIATE LEVELS OF ECONOMIC DEVELOPMENT, AND MODERATE LEVELS OF DIVERSE TECHNOLOGICAL CHANGE. THE GLOBAL MAP SHOWS THE PROJECTED CHANGE IN TEMPERATURE BETWEEN THE TIME PERIODS 1961 TO 1990 AND 2071 TO 2100. THE ARCTIC MAP SHOWS CLIMATE CHANGE FROM 1990 TO 2090.

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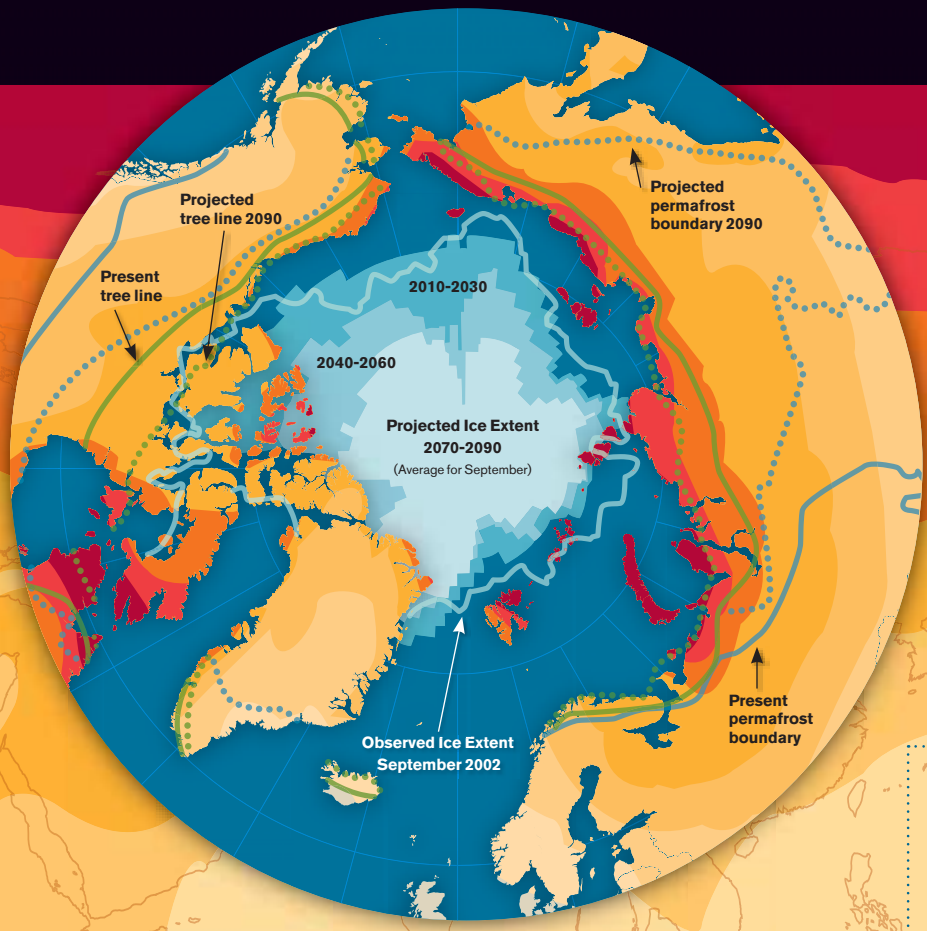



**FORECASTING:** The United Kingdom's Centre for Global Atmospheric Modelling is using one of the world's most powerful supercomputers to produce more-reliable long-term weather predictions in order to help nations prepare for the impact of climate change. The "Earth Simulator," located in Yokohama, Japan, is capable of sustained performance of 35.86 teraflops, has a main memory of 10 terabytes and is housed in a building the size of four tennis courts.

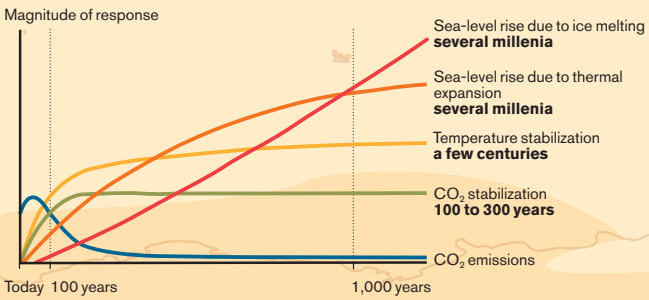
**HYDROGEN:** Tokyo Gas launched the world's first residential fuel-cell system in early February. In this pilot project, a homeowner can lease a unit that extracts hydrogen from natural gas and uses it to generate enough electricity to meet about 60 percent of the demand of a typical four-person household. Each unit will reduce a home's annual greenhouse-gas emissions by approximately 40 percent. The 10-year lease will cost 1 million yen ($9,607), and savings from reduced energy usage will not entirely cover the cost of the lease; the shortfall is about 40,000 yen ($384) per home per year.

Projected change in mean temperature over the next century (°C)


**METHANE REDUCTION:** Livestock, which belch and otherwise generate great amounts of methane, account for more than half of New Zealand's greenhouse-gas emissions. The Pastoral Greenhouse Gas Research Consortium funds research aimed at reducing methane production from grazing animals; its projects include the development of new feed formulations and the identification of viruses that could selectively kill gas-producing bacteria in livestock's rumens.

### Time to Equilibrium

Climate-change experts predict that even when emissions are curtailed, their effects on the environment will continue to be felt for hundreds, even thousands, of years.




SOURCES: INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, ARCTIC CLIMATE IMPACT ASSESSMENT, U.N. FRAMEWORK CONVENTION ON CLIMATE CHANGE

TRENDS

# Declaring Biowar on Cancer

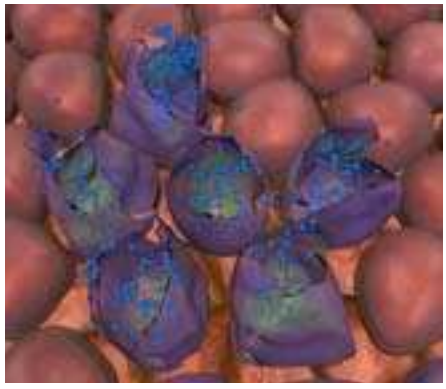
## Viruses may be a mighty new weapon

**THE ANTHRAX LETTER** attacks of 2001 drew a lot of attention to the question of biological warfare, sparking fears that terrorist-funded biologists could create "superbugs," bacteria or viruses designed to kill. But efforts to build designer bugs are not always malicious. In one unusual form of biological attack, researchers are engineering viruses to seek and destroy the cells that run amok in cancer patients. After more than 10 years of lab work, researchers in the field of "oncolytic therapy" have reached a sort of critical mass, deploying their designer viruses in a number of human trials.

The idea is astonishingly simple: let viruses do what they always do—but only to cancer cells. All viruses infect host cells and trick them into replicating the virus until the cells burst, releasing the new viruses. But unlike other viruses, oncolytic, or cancer-bursting, viruses reproduce in and destroy only cancer cells, leaving normal cells pretty much alone. "Viruses are a parasite, and they want to grow in cells that replicate very effectively to have the highest opportunity for themselves to replicate," says Matt Coffey, chief scientific officer of Oncolytics Biotech in Calgary, Alberta. "Cancer cells fit that bill."

Researchers usually begin by choosing a virus that replicates and kills cells aggressively, such as herpes simplex virus, tinkering with the genes it needs to reproduce so the organism grows exclusively in cancer cells, sometimes even targeting specific types of tumors. In some cases, genes are also added to the virus to give it an extra punch: the virus might produce a protein that, for instance, converts a nontoxic drug into a potent chemotherapeutic agent only in cancer cells or revs up the patient's immune system to attack the tumor.

Several oncolytic viruses have entered human tests. Robert Martuza, a neurosurgeon at Massachusetts General Hospital and Harvard Medical School and a pioneer of oncolytic therapy, has done human safety tests of mutated herpes strains against brain cancer, for instance. Kenneth Tanabe, chief of surgical oncology at Massachusetts General, is participating in a liver-cancer clinical trial of a herpes strain owned by German biotech company Medigene. The company will also soon begin human tests of a strain targeted against brain cancer. Oncolytics Biotech is currently conducting clinical tests on how reovirus performs against an aggressive brain cancer called glioblastoma multiforme, as well as several different solid tumors. Cell Genesys, based in South San Francisco, CA, is developing cancer-targeted versions of adenovirus, often the culprit behind the common cold; one is already being tested in prostate cancer patients, and another should enter clinical trials against bladder cancer early this year.



**Oncolytic viruses (blue dots) kill cancer cells (purple) by bursting them, but leave healthy cells (pink) unscathed.**

COURTESY OF ONCOLYTICS BIOTECH

One expectation of all these groups is that oncolytic therapies will not only treat previously incurable cancers but also help eliminate some of the worse aspects of cancer care. Although test patients sometimes suffer the low fevers or mild malaise typical of viral infection, none have shown the severe side effects associated with chemotherapy and radiation. Viral therapy should also enable doctors to destroy tumors without harming nearby tissue, a common problem with radiation and surgical treatments. Early results from the human tests have been promising; some patients experienced significant tumor shrinkage.

Still, oncolytic therapies face a major hurdle. As David Bartlett, chief of surgical oncology at the University of Pittsburgh Medical Center Cancer Centers, explains, "The single biggest drawback on all of these viruses is the host immune system reaction," which attacks oncolytic viruses as it would any other virus. Many people have existing immunity to common viruses, such as herpes and adenovirus; were such people to undergo oncolytic therapy, their immune systems could destroy the viruses before they ever infected the cancer cells. The reaction could also preclude multiple rounds of treatment, since patients could develop immunity to the engineered virus after the first exposure.

Researchers are exploring ways of coping with patients' immune reactions to oncolytic viruses. One possibility is to administer the virus directly to the tumor, largely bypassing the blood-based immune system. Or the immune system might turn out to be as much friend as foe. "The immune system will attack the virus," says Martuza. "But at the same time, it will attack the cells the virus is growing in, so you'll get a rejection not only of the virus but also of the cancer cells."

It will almost certainly be several years before the first oncolytic viruses receive federal approval and become first-line therapies for cancer, but with more than a decade of experience behind them, researchers are optimistic that they will eventually succeed. "I don't honestly know which of these viruses is going to work, and it may turn out that one will work for one type of cancer, one for another type of cancer," says Martuza. "It almost doesn't matter. It's a blossoming field, and some of them will end up working." **ERIKA JONIETZ**

**PROTOTYPE**

# Alternative Solar

Mirrors focus the sun's rays on a device that drives a generator.

Solar cells promise clean and unlimited energy, but they're notoriously inefficient at converting the sun's rays into electricity. Phoenix's Stirling Energy Systems and Sandia National Laboratories have teamed up to field-test an alternative solar technology that promises twice the efficiency of conventional silicon solar cells. (Efficiency is defined in this case as electricity produced per watts of sunlight falling on a given area.) The researchers have built a prototype power plant using six solar-powered engines. Each engine consists of a large dish, 11.6 meters in diameter, made up of 82 mirrors. The mirrors focus the sun's rays onto a receiver containing a bundle of small hydrogen-filled metal tubes. The gas expands when it's heated by the solar rays and cools as it passes through heat exchangers. This expansion and contraction drives pistons, which in turn drive a generator. Though individual solar-dish engines have already been tested as a way to provide on-the-spot power for remote locations, this is the first time anybody has used them to build a power plant. Stirling Energy Systems' aim is to build plants with thousands of engines and sell the power—enough for tens of thousands of homes—to utility companies. The company is in discussions with utility companies in Arizona, California, Nevada, and New Mexico and hopes to have its first commercial plant running by 2007.

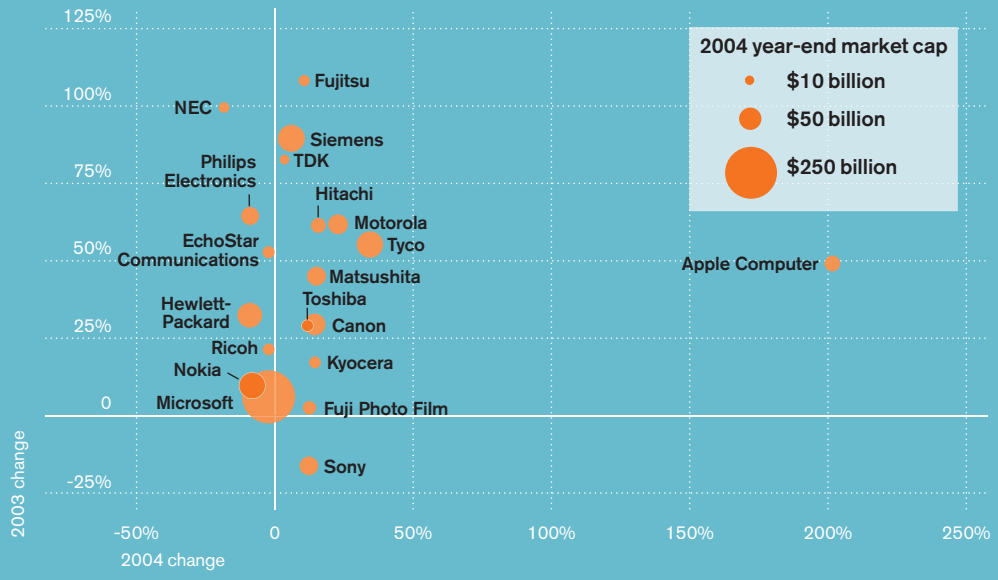
RANDY MONTOYA, SANDIA NATIONAL LABORATORIES

**METRICS**

# iPod Impact

A look at the performance of the top 20 consumer electronics stocks shows just how far the iPod apparently pulled Apple Computer away from the pack. Apple registered a 201 percent appreciation in share price in 2004, on top of a 49 percent appreciation in 2003. (Microsoft's stock was flat in both years.) Sales of 4.6 million iPods during the last three months of 2004 helped drive Apple to $3.5 billion in quarterly revenue—the highest ever recorded by the company.

**Market capitalization and annual change in share price for 2003 and 2004**




TOP 20 CONSUMER ELECTRONICS STOCKS BASED ON MARKET CAPITALIZATION AS OF DECEMBER 31, 2004. NOTE: ALTHOUGH DIRECTV'S MARKET CAPITALIZATION PUTS THE COMPANY IN THE TOP 20, IT IS NOT INCLUDED HERE BECAUSE ITS SHARES WERE NOT LISTED UNTIL DECEMBER 2003. SOURCE: REVERE RESEARCH.

STARTUP

# Search for Couch Potatoes

## Results are automatic, keywords are optional


**TODAY'S COMPUTER HARD** drives look a lot like the Web: huge, cluttered collections of content that can make it nearly impossible to find a file manually. So it's no surprise that Web-search giants like Google and Yahoo are competing to make the best hard-drive search engine. Attempting to keep up in this race to conquer what's known as "desktop search" is Blinkx of San Francisco. The startup's software turns search on its head: instead of waiting for the user to type keywords in a query box, the software monitors what the user is working on and automatically supplies links to relevant content from the local hard drive and the Web.

The race heated up in October with the release of Google's desktop search engine. Since then, MSN, Ask Jeeves, and Yahoo have come out with competing products. But even last summer, Blinkx had its software ready to download. It has since accumulated a million active users.

Like all desktop search engines, the Blinkx software runs on the user's computer and indexes the contents: word-processing documents, e-mails, and so forth. Once that's done, the software "reads" whatever the user is working on—basically anything with text—and matches the pattern of words in that file with those in files stored on the hard drive and on the Internet. A toolbar at the top of every program window lets the user choose which of the files uncovered in this search she'd like to view: documents on the hard drive, news stories, Web pages, even online video clips.

Delivering search results automatically is one thing that distinguishes Blinkx's search tool from that of its competitors. Another is that Blinkx errs on the side of providing too few rather than too many results, trying not to inundate users with not-so-relevant links, as some keyword-based search engines tend to do. "When you pick only a few keywords to search, you lose lots of detail and context," says Suranga Chandratillake, Blinkx's cofounder and chief technology officer. "We get to keep all that context, and that's why we get such good results." Of course, whether users will agree about the superiority of the results will depend to a great extent on personal taste. Users will notice that for most documents, the Blinkx toolbar will only bring up three or four results—and sometimes none—which may disappoint those accustomed to copious hits from traditional search engines. In that case, users have the option of crafting their own queries in a separate query box.

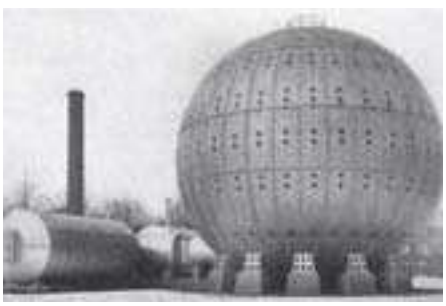
With $10 million in funding from private individuals, Blinkx says it has enough money to last at least though the year without seeking venture capital financing. The company's first goal is to get more users to download its software. One way to do this, says Blinkx CEO Mark Opzoomer, is to partner with companies such as online retailers and publishers; a branded button on the Blinkx toolbar would only return results from the partner company's site. Because downloading the toolbar is free, Blinkx will rely on advertising—in the form of a separate ad button on the toolbar—to bring in revenue.

With a million users, Blinkx is off to a good start. But capturing the next million will be tough. Blinkx will have to reach out to the masses, who may be more apt to try new kinds of searches from trusted companies like Google and Yahoo. Attracting advertising may also be difficult. While it's easy for advertisers to link their ads to keyword searches, it may be more difficult to place ads that are relevant to the contents of personal files, says David Burns, CEO of a competing desktop search company called Copernic of Sainte-Foy, Quebec.

Perhaps the biggest worry is Microsoft. Long before Blinkx came along, the software giant talked about automatic searching based on what a user is working on, a concept it calls "implicit query." Microsoft researchers have demonstrated prototype hard-drive search software that incorporates this feature, and it may very well be a part of the next version of Windows. If so, Blinkx—which beat Microsoft to market with implicit query—could end up being overtaken by the behemoth. **CORIE LOK**

MONIKA AICHELE (TOP); EWING GALLOWAY

### 75 YEARS AGO IN TECHNOLOGY REVIEW



Sanitarium for oxygen treatment built in Cleveland by H. H. Timkin, after successful experiments by Dr. O. J. Cunningham of the University of Kansas. Patients live in the sphere under a pressure of five to thirty pounds above normal. *(March 1930, p. 237)*

# The Darwinian Interlude

## Biotechnology will do away with species. Good: cultural evolution is better than natural selection.

**Freeman Dyson** is professor emeritus of physics at the Institute for Advanced Study in Princeton, NJ. His research has focused on the internal physics of stars, subatomic-particle beams, and the origin of life.

CARL WOESE PUBLISHED a provocative and illuminating article, "A New Biology for a New Century," in the June 2004 issue of *Microbiology and Molecular Biology Reviews*. His main theme is the obsolescence of reductionist biology as it has been practiced for the last hundred years, and the need for a new biology based on communities and ecosystems rather than on genes and molecules. He also raises another profoundly important question: when did Darwinian evolution begin? By Darwinian evolution he means evolution as Darwin himself understood it, based on the intense competition for survival among noninterbreeding species. He presents evidence that Darwinian evolution did not go back to the beginning of life. In early times, the process that he calls "horizontal gene transfer," the sharing of genes between unrelated species, was prevalent. It becomes more prevalent the further back you go in time. Carl Woese is the world's greatest expert in the field of microbial taxonomy. Whatever he writes, even in a speculative vein, is to be taken seriously.

Woese is postulating a golden age of pre-Darwinian life, during which horizontal gene transfer was universal and separate species did not exist. Life was then a community of cells of various kinds, sharing their genetic information so that clever chemical tricks and catalytic processes invented by one creature could be inherited by all of them. Evolution was a communal affair, the whole community advancing in metabolic and reproductive efficiency as the genes of the most efficient cells were shared. But then, one evil day, a cell resembling a primitive bacterium happened to find itself one jump ahead of its neighbors in efficiency. That cell separated itself from the community and refused to share. Its offspring became the first species. With its superior efficiency, it continued to prosper and to evolve separately. Some millions of years later, another cell separated itself from the community and became another species. And so it went on, until all life was divided into species.

The basic biochemical machinery of life evolved rapidly during the few hundred million years that preceded the Darwinian era and changed very little in the following two billion years of microbial evolution. Darwinian evolution is slow because individual species, once established, evolve very little. Darwinian evolution requires species to become extinct so that new species can replace them. Three innovations helped to speed up the pace of evolution in the later stages of the Darwinian era. The first was sex, which is a form of horizontal gene transfer within species. The second innovation was multicellular organization, which opened up a whole new world of form and function. The third was brains, which opened a new world of coördinated sensation and action, culminating in the evolution of eyes and hands. All through the Darwinian era, occasional mass extinctions helped to open opportunities for new evolutionary ventures.

Now, after some three billion years, the Darwinian era is over. The epoch of species competition came to an end about 10 thousand years ago when a single species, *Homo sapiens*, began to dominate and reorganize the biosphere. Since that time, cultural evolution has replaced biological evolution as the driving force of change. Cultural evolution is not Darwinian. Cultures spread by horizontal transfer of ideas more than by genetic inheritance. Cultural evolution is running a thousand times faster than Darwinian evolution, taking us into a new era of cultural interdependence that we call globalization. And now, in the last 30 years, *Homo sapiens* has revived the ancient pre-Darwinian practice of horizontal gene transfer, moving genes easily from microbes to plants and animals, blurring the boundaries between species. We are moving rapidly into the post-Darwinian era, when species will no longer exist, and the evolution of life will again be communal.

In the post-Darwinian era, biotechnology will be domesticated. There will be do-it-yourself kits for gardeners, who will use gene transfer to breed new varieties of roses and orchids. Also, biotech games for children, played with real eggs and seeds rather than with images on a screen. Genetic engineering, once it gets into the hands of the general public, will give us an explosion of biodiversity. Designing genomes will be a new art form, as creative as painting or sculpture. Few of the new creations will be masterpieces, but all will bring joy to their creators and diversity to our fauna and flora. ■

# Microsoft: Getting from "R" to "D"

## The software giant's Beijing lab is spearheading a new way to turn research into products.

Can a firm have too much innovation to handle?

It happens. And that problem was the dominant issue for a small group of executives from Microsoft's Beijing research lab when they held a retreat in November 2002 at a spa in Zhuhai, not far from China's border with Macao. Relaxing in the outdoor hot springs, the group brainstormed a promising solution to a fundamental problem facing Microsoft and many other high-tech companies: how to move more innovations more swiftly and effectively from research to development to market. Their idea: a new type of organization designed to bridge the gap between "R" and "D" and in the process overcome many of the product development bottlenecks and geographic and cultural differences that impede today's global corporations.

Microsoft's Advanced Technology Center (ATC) opened in November 2003 with 20 employees and a couple of projects. By late last year, after receiving more than 30,000 résumés from around China and sparking keen demand among Microsoft's business divisions, it had around 100 employees, with some 17 major projects and scores of minor ones on its books; this year, the ATC is set to double in size. In the next few years, the center expects to be the key technology transfer point for a host of new products, from Web-search technologies to mobile applications and home entertainment systems. On the strength of these innovations, Hongjiang Zhang, the center's charter director, hopes to provide a powerful alternative to Microsoft's traditional strategy of creating products in the U.S., spiraling into Europe, and then adapting them for the Chinese market. "China is still emerging, but China is no longer just a follower," he says. "They are starting to lead."


GREG BAKER/AP

### Microsoft Advanced Technology Center

**Location:** Beijing, China
**Founded:** November 2003

**The case:** As China evolves from technology follower to world leader, Microsoft has created a new type of organization to speed innovations to the local market—and beyond.

So why not complement the current strategy by growing and testing new products in China and then introducing them in the United States?

### Necessity: Mother of Development

ATC takes up half of one floor of a six-floor office building in the Haidian district of northwest Beijing—the same edifice occupied by Microsoft Research Asia, one of six research labs worldwide that Microsoft operates. Enhancing the transfer of technology between the 170-strong research facility and product development groups at Microsoft's headquarters in Redmond, WA, is the whole reason the center exists, and the close proximity to the lab makes handoffs easier.

Zhang, who worked on technology transfer at Hewlett-Packard Labs before being recruited as a charter researcher at the Beijing lab, says the issues spurring the ATC's creation are common to all research and development–driven organizations. After researchers hand off an invention or a new piece of code to product developers, a lot of refinement and testing is needed to get it ready for commercial release, and the product developers aren't always able to do it. They often have their hands full with more pressing jobs—say, upgrading conventional features or improving security. And even a great invention might arrive at the wrong point in the product development cycle, where it's difficult to fit into the next release. "Which means that for the product group to form a team and take that risk [of developing the invention] may be too big a risk and too big a distraction," says Zhang.

His sentiment is echoed by Dennis Adler, general manager of business development for ATC. Based in Redmond, he is the liaison between the center and Microsoft's product groups, helping the business divisions understand what advances are emerging from Beijing and the ATC members understand development schedules and constraints. Many times, he says, product groups would have loved to incorporate some cool feature or technology created in one of Microsoft's research labs but just didn't have the staff to devote to it. "There are tech transfers that haven't happened because of it," he says. "So ATC was set up as a way to help close that gap. It's all about lowering the impedance."

Microsoft officials say they know of nothing else like the Advanced Technology Center either inside their company or outside it. "We just invented it," says Adler. At least in Beijing, an organization like the center wasn't even thinkable until a few years ago, and its creation shows the benefits of constantly adapting operations as conditions change.

Given that it typically takes several years for research projects to yield anything that can be commercialized, moving innovations to development was hardly a

top priority when the Beijing lab was formed in 1998. Early on, though, a group was set up to help researchers build demos for showing concept technologies to their Redmond research colleagues and to the business divisions—with two engineers or programmers assigned to each of about a dozen projects. But as the lab grew, and its projects became serious contenders for product development, it became clear that while one project might require only two engineers or programmers, another might need five or more to handle the intensive testing and predevelopment refinement needed to verify that a one-of-a-kind research prototype could be mass produced.

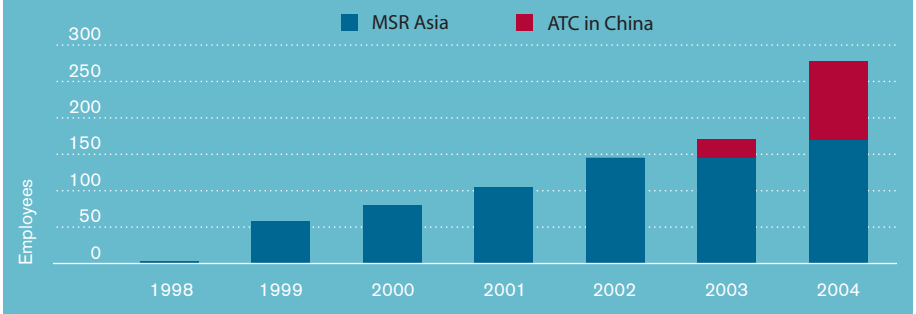
The initial solution, in late 2001, was to form a centralized, more flexible organization dedicated to technology transfer. Rather than being assigned to specific lab projects, engineers in the new Technology Transfer Group (TTG) went where they were needed—in the numbers needed. The new group marked a big step forward, says Zhang. But as the lab matured, more of its research teams produced more promising technology. "Now the scale is bigger," Zhang says. So something bigger than the TTG was needed.

In addition to Hongjiang Zhang, the group that assembled at the hot-springs retreat in late 2002 included Ya-Qin Zhang (no relation), who headed the Beijing research lab from mid-2000 until early 2004, before becoming vice president of Microsoft's Mobile and Embedded Devices division. They were joined by Harry Shum, then number two at the lab and now its director, and a handful of other key personnel.

Central to their thinking was China's status as more than just an emerging market. Thanks to places like the Beijing lab, the country was making its mark in the creation of information technology, and the spa-soakers figured that a different type of organization, larger and more systematically woven into Microsoft's product-development cycles than the Technology Transfer Group, might help the company take advantage of that creativity far more effectively. "That's how the ATC concept started," says Ya-Qin Zhang, who came up with the initial idea. "It's an incubation center for new technology"—technology made in China.

## Growth of Microsoft's Asian Research Operations

Microsoft's Advanced Technology Center in China has quadrupled in size in one year.




SOURCE: MICROSOFT

### Ballmer's Key Recommendation

A few days later, Ya-Qin Zhang formalized the idea in a proposal to Microsoft's senior vice president Rick Rashid, who oversees Microsoft Research's worldwide operations. The plan focused on four prime goals: amplifying technology transfer by moving more products to development more efficiently; tapping Chinese talent in new ways; preparing for an emerging Chinese market hungry for cool new things; and incubating technology created in China in order to spread it to the rest of the world.

Rashid embraced the concept and asked for a detailed proposal. He then took the plan to Bill Gates, laying out the initial projects the center would take on and requesting a 50 percent increase in Beijing lab staff. The Microsoft chairman gave the plan the green light.

The last person to convince was CEO Steve Ballmer, who had to approve new personnel additions of this magnitude. Ballmer surprised Rashid by asking whether the 50 percent staff increase was adequate. His point was that by the time an innovation made it to the new Advanced Technology Center, it should be pretty much assured of becoming part of a commercial product. Therefore, unlike the research division, whose projects usually face a less certain future, ATC should have no rigid size limit. Ballmer told Rashid, "I am going to eliminate the ceiling." Moreover, he noted, since the product groups would be the main beneficiaries of the new center, they should pay for the predevelopment effort.

Hongjiang Zhang says that Ballmer is "very smart" and that his funding idea proved particularly astute. When product groups pony up for an ATC project, he notes, they have a bigger stake in making it work, increasing the odds of success.

The Advanced Technology Center's opening in November 2003 was timed to coincide with the five-year anniversary of Microsoft Research Asia. To help handle the flood of résumés that poured in, Zhang began holding written exams in 11 cities around China, with two sessions in late 2003, one in February 2004, and two in October and November 2004. Late last year, the center also began using one of the Beijing lab's prototype technologies, a résumé screener that categorizes candidates by test scores and other parameters and gives priority to graduates of top computer science and engineering programs.

Zhang and Beijing lab managing director Harry Shum almost glow with excitement when they talk about the talent that those résumés represented. They wasted no time in putting their new hires to work. The first product to go to market was a video-editing technology that can easily summarize sports and news highlights, compressing an hour of video into five minutes. The software is now standard in Movie Maker 2.1, part of Windows XP. The Windows XP Media Center Edition 2005, a version of the XP operating system designed to make it easy to manage home

entertainment from a PC, also features technologies created by the Beijing research lab and further developed by ATC. These include automatic image processing for digital photos and a function that automatically locates the center of attention in a photograph and highlights the area most likely to be cropped.

At the beginning of 2005, Microsoft was closemouthed about projects now in the ATC pipeline—projects it expects to yield commercial products within the next two years. But Zhang says six of Microsoft's business divisions currently fund projects inside ATC.

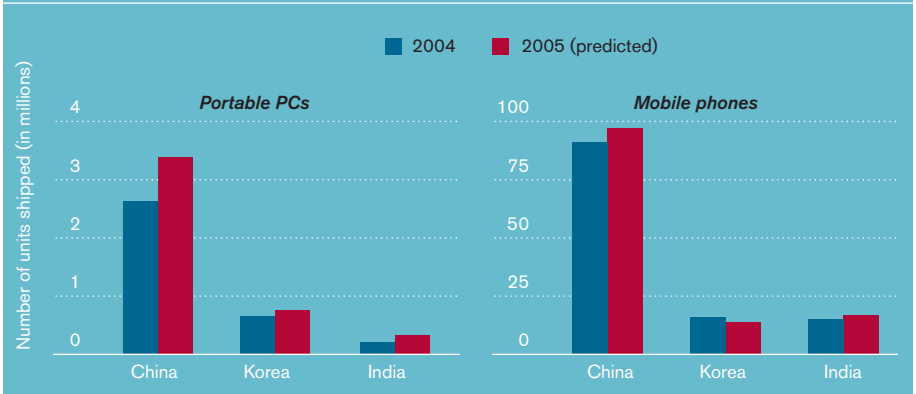
One big push, he hints, will be in search technology. Microsoft researchers have been working in search for a decade and, says Zhang, the Beijing lab has been at it for five years. It's only natural to expect that some of that work is nearing commercialization, presumably for Microsoft's MSN Internet portal business and the Windows Client group, which is responsible for the company's operating systems.

The Natural Interaction and Services division now run by Kai-Fu Lee, who founded the Beijing lab in 1998, is also sponsoring several projects. But ATC's biggest customer is the Mobile and Embedded Devices division. "We're putting a lot of focus on mobility," says ATC assistant director Eric Chang. "China is the number one market with the handset, and the penetration rate is really low, so I think it will stay number one for a long time." Chang says the center is building a team to work more closely with handset operators and manufacturers to more quickly create new technologies and get them into products.

Heading Microsoft's mobile business, of course, is Ya-Qin Zhang, who conceived the Advanced Technology Center notion in the first place and is intimately familiar with the work being done in Beijing. Zhang couldn't be happier with his creation. "ATC is a super success," he says. "ATC now in Redmond is a star organization. Every product group wants to work with ATC." Although the center is focused on Beijing lab creations, Microsoft officials say it could eventually handle innovations from the company's other research groups* in Cambridge, England; Bangalore, India; Palo Alto and San Francisco, CA; and even Redmond.

## Asia Goes Mobile

China will ship more than 96 million mobile phones and three million laptops in 2005.




SOURCE: IDC

### Future Concerns

It hasn't all been smooth sailing. Hongjiang Zhang says the biggest challenge so far has been helping the rush of new hires, many fresh from Chinese universities, fit into the Microsoft culture and development process. An English writer has been hired to proofread important e-mails and documents before they are sent. However, Zhang says, "We quickly realized the communication barrier is beyond just English. It's really about culture differences. How do you follow up? How do you work with a team that is 16 hours away and follow through on all the deliverables? Or how do you simply say no clear and loud in technical or project discussions and learn not to overcommit?" To help with such issues, the center has created programs to train future managers, and senior managers say they work diligently to share their experiences with new employees.

Dennis Adler, the ATC liaison in Redmond, visits Beijing several times a year and hosts ATC visitors monthly. In addition, he relies on an array of communications tools—e-mail, voice over Internet, instant messaging, videoconferencing—to overcome the time and distance gap between his Beijing colleagues and him. "You just have to work a lot harder to keep the communication up," says Adler.

**WWW.TECHNOLOGYREVIEW.COM** How have Microsoft's research labs contributed to its products? Keyword **MSR**.

And potentially rougher waters lie ahead. Managing the center's growth will be difficult as it steams past the 200-employee mark sometime this year. "Growing is easy, but to sustain it is hard," says Bin Lin, ATC's director of engineering. As more and more employees come on board, it becomes harder to maintain quality and meet deadlines, Lin says, and center leaders risk becoming so preoccupied with managing the here and now that they miss new opportunities.

Another problem facing organizations like ATC is that after a year or so of learning the ropes, their engineers might be lured away by Chinese firms, says Henry Chesbrough of the Center for Open Innovation at the University of California, Berkeley's Haas School of Business. Because they are not doing real research, the engineers lack the benefits of a research environment that might entice them to stay, such as freedom from the tight deadlines of product development schedules, Chesbrough says. And because their job trains them to solve product development problems, they have skills that are enormously attractive to other companies.

Hongjiang Zhang is well aware of the potential pitfalls. But he allows himself a little time to bask in the center's early success. Zhang says he was especially touched when Senior Vice President Rashid told him, "Without ATC, a lot of the things Microsoft should do and wanted to do will never happen."

ROBERT BUDERI, IN BEIJING

# Genetic Savings and Clone: No Pet Project

## Can it cash in on cloned cats?

A scientific victory can quickly devolve into a public-relations disaster, as Lou Hawthorne, CEO of Genetic Savings and Clone (GSC), learned the hard way in February 2002. Researchers funded by GSC at Texas A&M University in College Station, TX, had just produced the world's first cloned cat, CC. The achievement was a critical step toward GSC's goal of helping bereft pet owners duplicate their aging or deceased cats and dogs. The problem: CC wasn't a very faithful copy. She was a gray tiger tabby and looked nothing like her genetic donor, an orange calico named Rainbow.

The scientific explanation was simple. The color of a calico's coat is determined by genes on its X chromosomes, and in each cell of a calico's body, one of the two X chromosomes is randomly inactivated. In the cell scientists took from Rainbow's body to make CC, the orange-coat genes were apparently dormant. But disparaging newspaper reports didn't capture these details, and Texas A&M's communications staff didn't try very hard to explain them, says Hawthorne. "The line they used again and again was, 'We always said it was reproduction, not resurrection,'" he recalls. "Which could not be better engineered to damage our brand than if they had just said outright, 'Clones won't resemble their donors.' Who would want a cloned pet if the resemblance is not going to happen? That is what we are selling! It doesn't get worse than that for a pet-cloning company."

Of course, there aren't any other pet-cloning companies—which means GSC has had to craft its own solutions to a series of unusual business problems, of which the Texas debacle was only the first. The company's biggest challenges: disentangling the company from its origins in academe and then finding the techniques needed to avoid future CCs and turn pet cloning into a reliable, assembly-line-like process. Then there are the inevitable charges from critics* that pet cloning is dangerous, exploitative, sacrilegious, or wasteful. The San Francisco *Chronicle*, for example, has referred to GSC's cloned cats as "Frankenpets," and columnist Debra Saunders has called for a moratorium on pet cloning.

Indeed, the company's undeniable eccentricities make it an easy target. Its capital, for example, comes solely from 84-year-old billionaire John Sperling, a notorious business maverick who made his fortune by founding the for-profit University of Phoenix. In recent years, Sperling has raised eyebrows by investing tens of millions in the controversial fields of antiaging science and medical marijuana legalization. Hawthorne, meanwhile, is hardly a typical science-educated biotech CEO; rather, he is a former filmmaker, interactive media producer, and former Zen practitioner who in 1996 documented Hell's Buddhas, a spiritual pilgrimage across India by motorcycle. Moreover, GSC has set its prices so high—$50,000 for a single cat clone—that only the wealthiest and most obsessed pet lovers are able to afford the service, at least for now.

* **WWW.TECHNOLOGYREVIEW.COM** What are opponents and advocates of cloning saying about Genetic Savings and Clone? Keyword **clone**.

VICTOR FISHER/GENETIC SAVINGS AND CLONE/POLARIS IMAGES

### Genetic Savings and Clone

**Headquarters:** Sausalito, CA
**Founded:** 2000
**Employees:** 30

**The case:** What began in 1997 as a quixotic quest by billionaire educator John Sperling to clone a dog named Missy has grown into a busy company that delivered a cloned kitten to its first paying client in December. Transforming the former university project into a commercial service required not just a major investment from Sperling, but also an overhaul of the organization's scientific, operations, and media strategies.

Nonetheless, Hawthorne says Genetic Savings and Clone is a serious business and that Sperling is "a master of tough love" who expects a return on his investment. The company is already reaching its first critical milestones. But whether it can turn pet cloning into a profitable industry will hinge on what Hawthorne calls "the three pillars" of the company's business strategy: cutting-edge science, scalable operations, and extensive communications.

It was over breakfast with Hawthorne in 1997, shortly after Dolly the sheep made headlines as the world's first mammalian clone, that Sperling decided he wanted to clone Missy, a high-spirited Border collie-Siberian husky mix belonging to his friend Joan Hawthorne (Lou

Hawthorne's mother). Hawthorne wrote a feasibility study, Sperling gave the go-ahead, and thus was born Missyplicity, a three-and-a-half-year, $4-million project assigned to Texas A&M cloning expert Mark Westhusin and his team.

Dog and cat lovers across the country greeted the project with enthusiasm, writing in to ask whether they, too, could have their pets cloned. The apparent demand inspired Sperling and Hawthorne to build a commercial service around Westhusin's work, and, in 2000, Genetic Savings and Clone was incorporated. At first, the company existed mainly to fund the research at Texas A&M. But it also launched a "gene banking" service offering cryogenic preservation of clonable tissues from living or recently deceased pets; with charges ranging from $295 to $1,395, plus annual fees of $100 to $150, the service has provided GSC with a modest revenue stream.

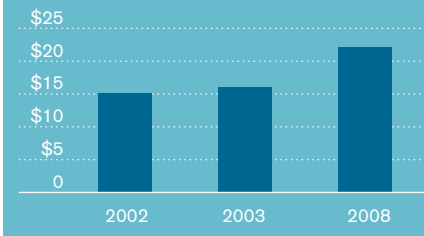
While GSC was getting off the ground, however, Missyplicity was stumbling. The Texas researchers were having trouble gathering enough eggs for their experiments. Worse, nuclear transfer—the technique used to clone Dolly and most other agricultural animals—was resulting in virtually no live, healthy, identical cat clones. Nuclear transfer involves removing the nucleus from an egg cell and infusing the egg with nuclear DNA from the donor's cell; the egg uses the new nuclear DNA to produce an embryo genetically identical to the donor. Unfortunately, this procedure is rarely successful.

Hawthorne says the Texas researchers resisted his pleas that they move beyond nuclear transfer and experiment with newer cloning techniques. When CC finally came along, she was a normal, healthy kitten, but her dissimilarity to Rainbow and the bad press that resulted was "the last straw" in the troubled relationship, Hawthorne says. It also precipitated a crisis of confidence within GSC. "We went through a really rough time. Maybe a third of the company was irretrievably negative about the future and about each other, and we had to get rid of those people. So there were some firings, there was some restructuring." Missy herself died in July 2002, at the age of 15 (her tissues were gene-banked).

GSC spent a year on the edge of failure. But in mid-2003, after months of lobbying, Hawthorne finally convinced Sperling that GSC should not renew its contract with the Texas project but instead build its own labs and buy rights to a new cloning technique called chromatin transfer, developed by Connecticut-based Aurox. In chromatin transfer, donor cells are first treated to remove molecules associated with cell differentiation from the donor cell; by doing so, the donor cell is reprogrammed to an undifferentiated state. As Hawthorne puts it, chromatin transfer produces healthy embryos at a rate that is "in the same ballpark with nature." GSC used the technique in 2004 to create the kittens Peaches, Tabouli, and Baba Ganoush, all identical copies of their genetic donors.

## U.S. Market for Pet Products and Services to Grow

Americans spent more than $16 billion on their pets in 2003.




SOURCE: PACKAGED FACTS, A PUBLISHING DIVISION OF MARKETINGRESEARCH.COM

In December, GSC delivered a cloned cat named Little Nicky to its first paying client. (Little Nicky's owner, an airline worker living in Dallas, says he is not only physically identical to the original Nicky, but even has the same behavioral traits, such as a predilection for climbing into people's hair.) Four more cloned kittens are on their way to clients. But GSC has "a ways to go before we break even," admits Hawthorne. "We spend millions of dollars a year on research, and last year we sold five clones at $50,000 each. That $250,000 won't even pay for the new microscope we're ordering."

The microscope will be part of a new $1-million cloning facility outside Madison, WI, scheduled to open this spring. On the science side, GSC is hiring some of the world's leading cloning experts to run the facility and to meet the challenge of dog cloning, which turns out to be even harder than cloning cats. This is because dogs are one of the rare mammalian species whose eggs are still immature when they leave the female's ovaries; the eggs must be exposed to a sequence of biochemical signals in the oviducts before they become usable for cloning. Relying on nature to mature the eggs would mean maintaining a large colony of female dogs, which only come into estrus twice a year; and even then, most naturally matured eggs burst when their nuclei are removed. But the company's new chief science officer, Philip Damiani, says those problems are already being overcome. Genetic Savings and Clone "has spared no expense to get the best equipment and the best people," Damiani says. "I see the company being around a long time."

On the communications side, GSC is aggressively open about its business: the Madison facility, for example, has a U-shaped observation hall with a glass-lined interior that allows journalists and TV crews to observe the entire cloning process. The company has also put substantial thought and money into logistics and operations. For example, it has built custom software to track gene banking, lab supplies, and clone development; created a network of spay clinics and dog breeders to ensure a constant supply of eggs and surrogates; and established a partnership with a London microengineering firm to build artificial oviducts for maturing dog eggs in the lab.

But first, GSC must prove it can clone dogs safely, increase production to dozens or hundreds of clones per year, and drastically lower its prices—all of which will take time. Fortunately, Sperling "doesn't make short-term commitments," says Hawthorne. (Sperling's investment will be managed by a foundation after his death.) And at least one payoff may come sooner rather than later: GSC expects to clone Missy by the end of this year.

That may not be a giant leap for biomedical science, says Hawthorne, but it will certainly please his mom. "Are we curing cancer?" he asks. "No, we are cloning pets. Is that something that increases the sum of joy in the world? We think it does."

**WADE ROUSH**

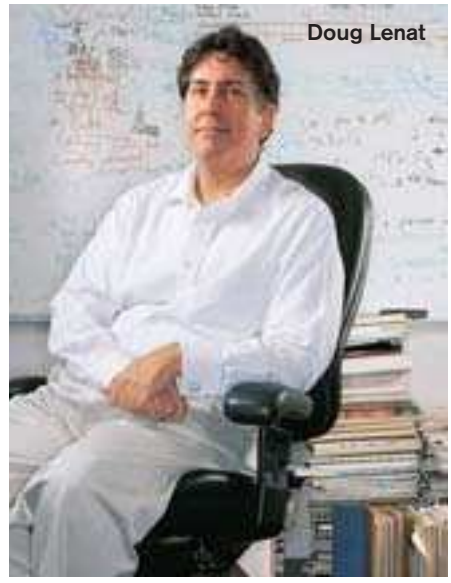
# Cycorp: The Cost of Common Sense

## How do you survive when it could take decades to build your product?

Ask most companies how they bring value to the market and they'll point to their products. Cycorp is a bit different. The 10-year-old company cares about the services it sells—but mainly because they bankroll its true quest: creating a "knowledge base" called Cyc that can endow computers with something approaching common sense. This quest has been so time-consuming that most venture capitalists would long ago have written off their investments—or demanded the CEO's head on a platter. That Doug Lenat and his 54 employees have avoided this fate is a lesson in managing long-term, visionary R&D projects.

Two decades ago, Lenat was a computer science professor at Stanford University with a dream of building a computer smart enough to know, for example, that people are smaller than houses and live in them. But he feared that, with just himself and a half-dozen grad students, programming such a computer would take more than a lifetime. Meanwhile, American high-tech leaders were worrying that the Japanese, with their so-called "fifth generation" artificial intelligence* development project, would do the same thing to the American computer industry that they had done to the automotive and consumer-electronics industries. So they set up a research consortium called the Microelectronics and Computer Technology Corporation (MCC). Lenat snatched at the backing offered by MCC, and went to work for MCC in 1984.

During its first decade, Cyc project managers merely had to report what they were doing to MCC once or twice yearly, recalls Lenat. That long-term backing was important because Cyc's creation involved inputting and organizing the millions of facts that, while seemingly obvious to humans, must be explicitly taught to computers in the logic they can understand. After reaching a certain level of sophistication, Cyc began to help direct its own education by asking questions based on what it already knew. (Lenat hopes that Cyc will eventually be able to read unassisted.) The result: a computer that doesn't have to be told that parents are older than their children and that people stop subscribing to magazines after they die.



Doug Lenat

### Cycorp

**Headquarters:** Austin, TX
**Founded:** 1994
**Employees:** 55

**The Case:** Cycorp has spent the last 10 years—and may have to spend another 20—amassing a database of the tiny facts that a computer needs to mimic human common sense. To fund the visionary project, the company has had to make a few compromises along the way.

Cyc's first big step into the real world came in 1994, when the project was spun off from MCC as an independent company, Cycorp. The challenge: how to keep funding a project that was still years, if not decades, away from commercialization. "In 1996, we got our first substantial government contract," Lenat recalls. Since then, Cycorp has collected about half of its revenue from U.S. government agencies and the rest from companies, mostly for building "semantic maps" that help users pull information from various databases with a single query. By taking on paying projects, Cycorp has been able to stay profitable and debt-free. All of the firm's stock is owned by its employees, making Cycorp answerable only to Cycorp. "But," Lenat admits, "we have had to tack with the funding winds. Maybe 50 percent of the funding we get pushes us forward in the direction that we need to go."

Cycorp doesn't even want to be distracted by the rigors of the retail software business; instead, it licenses Cyc for use in third-party software packages. A slimmed-down Cyc is available free to research organizations, and OpenCyc, an even smaller version suitable for desktop computers, is available as a free download. Lenat hopes that hobbyists will start adding terms, some of which would eventually be culled into the Cyc knowledge base, giving it grassroots input—and also establishing Cyc as the de facto artificial-intelligence knowledge base.

"The knowledge in Cyc has gotten quite good," says Ken Forbus, a professor of computer science at Northwestern University and a current user of ResearchCyc. "Is it perfect? No. Is it comprehensive? No. Is it broader than anything else out there? Yes."

The time may come, Lenat says, when a greatly expanded Cyc will underlie countless software applications. But reaching that goal could easily take another two decades.

LAMONT WOOD

**WWW.TECHNOLOGYREVIEW.COM** For a time line of previous attempts to create artificial intelligence, go to keyword **AI**.

WYATT MCSPADDEN

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# Tech+ Finance 2005


PHOTO ILLUSTRATION BY JOE ZEFF

# Follow the Money

## If you want to predict the future of emerging technologies, track who's spending what.

THE EDITORS

The appetite of venture capitalists for investing in new technologies is rebounding: in 2004, venture capital financing in the United States was up 8 percent from the year before, following three years of decline. With the success of Google's initial public offering (IPO) in August 2004, technology again excited the public imagination. Indeed, the window on IPOs opened wide in 2004, with 233 companies going public on U.S. stock exchanges and raising $43 billion, up from 79 companies and $16 billion in 2003. Biotechnology IPOs were particularly successful, raising $2.5 billion, the most since the $8.7 billion raised in 2000. So why are many of those involved in the funding of emerging technologies so worried?

According to some experts, the kind of basic research necessary to create tomorrow's technologies is under siege—or at the very least, suffering from neglect. Venture capitalists never entirely stopped investing in companies with technologies just emerging from the lab. But after several years in which high-risk investments were unpopular, many startups developing innovative technologies (especially in such areas as nanotechnology and new genomic approaches to medicine) are starving for capital. Even more worrisome, the federal government's preoccupation with funding homeland security and national defense, and its resulting cutbacks in support for basic research in other areas, has left many wondering where the funding for research on new core technologies will come from.

For many in the technology community, the threat of crisis became much more vivid in early December when President Bush signed off on the fiscal year 2005 U.S. federal budget. While this year's budget increases spending for research and development by 4.8 percent to $132.2 billion, most of that increase—80 percent—goes to defense R&D, and most of that to new weapons development, according to the American Association for the Advancement of Science (AAAS). In fact, defense-related R&D reached a record high $75 billion this year. One winner was the U.S. Department of Homeland Security, which gets a 19.9 percent increase in its R&D budget, to $1.2 billion. The big loser is the National Science Foundation (NSF), which had its R&D budget cut by .3 percent, to $4.1 billion; it was the first cut in NSF's budget since 1996. Meanwhile, R&D funding for the National Institutes of Health (NIH) increased by just 1.8 percent to $27.5 billion; it was NIH's smallest percentage increase in years, and well below the rate of inflation.

"Defense and homeland security are very important. I can't criticize funding increases per se in those areas," says Shirley Ann Jackson, president of Rensselaer Polytechnic Institute in New York and the 2004 AAAS president. "But the bigger issue is sustaining focus and support for funding of basic research across broad fronts. We have to have a robust base of basic research. We're talking about potentially eroding that base." Jackson adds, "Other places will innovate. The question is, are we going to be a leader? If we don't pay attention to the warning signs, 15, 20 years from now, we could find ourselves in

a relatively disadvantageous position in terms of global leadership."

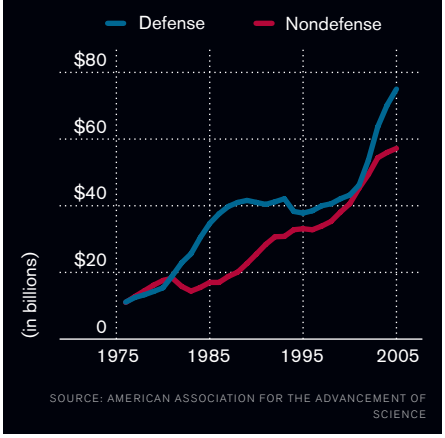
Experts also worry that the federal R&D budget has become too skewed toward relatively mature technologies. "A lot of the federal funding has gotten a little more conservative and risk averse. The government needs to put a bigger percentage in radical innovation and more-exploratory research—technology that's going to be transformational," says Deborah Wince-Smith, president of the Council on Competitiveness, a group of industry, university, and labor leaders based in Washington, DC. Amar Bose, professor emeritus at MIT and founder of the Bose audio company in Framingham, MA, puts it more bluntly: "Research funding is going downhill, and I don't see it turning around. We're going to have trouble."

The cutbacks in the federal budget are further exacerbated by the continuing trepidation of many venture capitalists. While valuations of later-stage venture-backed startups have begun to bounce back this year, valuations for younger startups have not. In addition, say experts, some venture capitalists are focusing on certain pockets of technology, such as those relevant to homeland security and biodefense, where the focus is more on developing and deploying existing, well-established technologies than on inventing innovative new ones. All of which could have dire consequences for innovative startup companies.

Indeed, the combination of venture capitalists favoring later-stage startups and the continuing trend of large corporations investing less in speculative research is creating an innovation vacuum, according to some experts. "The effects are pretty ghastly," says Lita Nelsen, director of MIT's Technology Licensing Office. "Large corporations have become less and less invested in early-stage research. They buy it from little companies. And if there's nobody to get the little companies started, we're getting it at both ends."

## Defense Soars

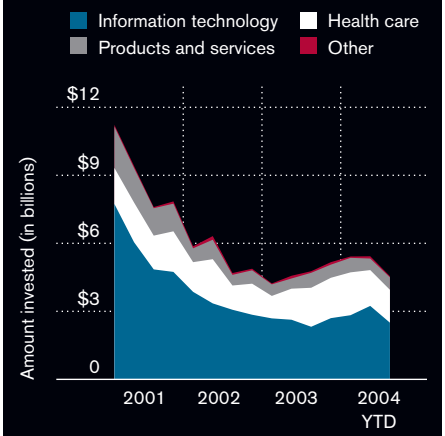
From a recent low of exactly half the federal R&D budget in 2001, defense R&D has climbed to 57 percent for this fiscal year.




SOURCE: AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

## Where VCs Spend

Even though venture capital funding dipped in the third quarter last year, overall, the first three quarters saw a 14 percent increase over the same period in 2003.




2004 DATA THROUGH Q3. SOURCE: DOW JONES VENTURE ONE

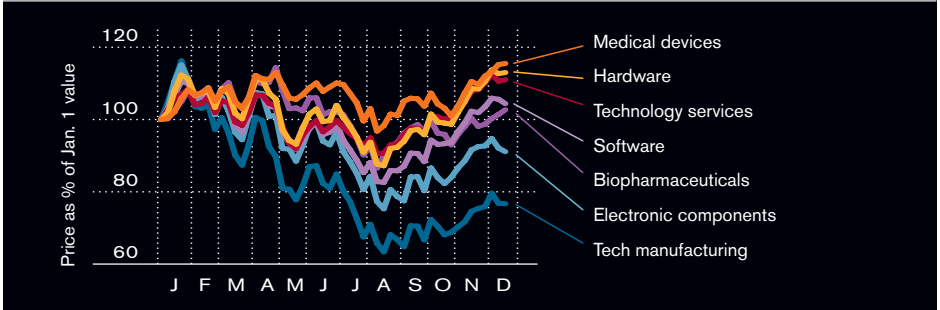
# 57

Percentage of the 2005 U.S. federal R&D budget that goes to defense

Despite these concerns, however, there are encouraging signs that investment in innovative technologies, at least in the private and public markets, began to regain favor last year. In particular, 2004 was a strong year for companies going public; the number of IPOs and the amount of money they raised reached their highest levels since 2000. What's more, the value of mergers and acquisitions involving venture-backed companies was 76 percent higher than in 2003—all of which means that venture capitalists once again have the prospect of lucrative exit strategies and the motivation to invest in startup companies. "Despite the disappointments, venture capital is still a way to make enormous riches," says Josh Lerner, a professor of investment banking at the Harvard Business School.

## Tech Stocks: A Mixed Year

In the public markets, the medical-device, hardware, and technology-services sectors saw stock prices improve by 10 to 15 percent last year. Tech manufacturing was the biggest loser.




AS OF DEC. 23, 2004. DATA INDEXED TO 100. SOURCE: REVERE DATA


# Private Markets

The collapse of Internet and telecommunications stocks in mid-2000 closed the IPO markets for all technology companies, damping the enthusiasm of venture capitalists, who frequently look to IPOs to repay them for their efforts. But with the revival of the IPO markets in 2004, venture capital financing is slowly returning, at least for more mature startups. Venture capital and private equity investments in 2004 were roughly $20 billion, a slight increase from $18.7 billion in 2003, according to estimates based on the annual end-of-the-year survey by PricewaterhouseCoopers, Thomson Venture Economics, and the National Venture Capital Association. And the prices of deals—especially deals with later-stage companies—are creeping back up. "We're seeing deals that wouldn't have gotten funded one or two years ago," says Allan Ferguson of 3i, a leading venture capital firm.

There are even encouraging, albeit tentative, signs of a renewed interest in early-stage startups. The valuations for companies receiving their first few rounds of venture investment remained flat from 2003 to 2004 and are still below 2000 and 2001 levels. But according to VentureOne, a venture capital research firm, early rounds of venture funding represented 33 percent of all rounds in the United States in 2004, reversing a downward trend that started in 2001, after early-stage venture investments peaked at 54 percent of the total in 2000.

In addition to the improved prospects for exit strategies, another reason for the rising prices of venture deals (at least four

## Top 10 Venture Capital Deals, 2004

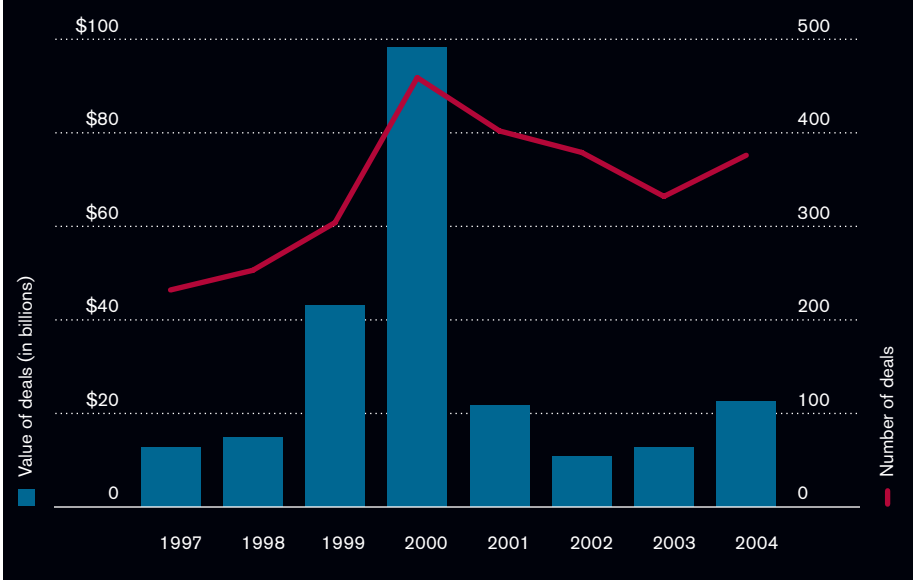
Pharmaceutical, telecom, and online companies led the year's venture capital fundings.

| Rank | Date closed | Company name | Sector | Amount raised (millions) | Product/service |
|---|---|---|---|---|---|
| 1 | 3/24 | Jazz Pharmaceuticals | Pharmaceuticals | $250 | Neurological and psychiatric treatments |
| 2 | 6/14 | RiskMetrics Group | Business applications software | $122 | Financial risk-management services |
| 3 | 12/11 | eHarmony.com | Online services | $110 | Online dating service |
| 4 | 8/25 | Vonage | Communications | $105 | Global digital telephony service |
| 5 | 1/20 | OptionsXpress | Financial services | $90 | Online options-trading services |
| 6 | 11/22 | Synta Pharmaceuticals | Pharmaceuticals | $80 | Treatments for cancer and chronic inflammation disease |
| 7 | 11/2 | Fastclick.com | Media | $75 | Online advertising services |
| 8 | 6/3 | Force10 Networks | Connectivity products | $75 | Ethernet routing and switching equipment |
| 9 | 5/10 | Mahi Networks | Fiber-optic equipment, photonics | $70 | Metro transport and switching platforms |
| 10 | 5/21 | TechTarget | Online content providers | $70 | Network of industry-specific IT websites |

SOURCES: DOW JONES VENTUREONE, THOMSON VENTURE ECONOMICS, AND THE NATIONAL VENTURE CAPITAL ASSOCIATION AND NEWS REPORTS

## Shopping for Venture-Backed Companies

Though the number of venture-backed merger and acquisition deals in the U.S. increased by only 13 percent, their value actually grew by 76 percent.




SOURCE: DOW JONES VENTURE ONE

JOE MAGEE

# 200 *million*

## Amount of venture funding raised by nanotech companies

startups, Jazz Pharmaceuticals, RiskMetrics Group, eHarmony.com, and Vonage, each raised more than $100 million in 2004) is that limited partners—the pension funds, endowments, and others that provide the capital to venture funds—are putting their money to work again, investing it in venture capital funds. At the same time, billions of dollars committed to venture capital funds since 2000 remain unspent. Venture capitalists are coming under pressure to invest this money soon; the consequence is that more companies are getting funded, and later-stage deals are getting bigger.

But for the most part, companies just starting up are still struggling. And venture funding for one of technology's most speculative, albeit promising, fields has been one of the biggest casualties. Venture funding for nanotechnology dropped from $386 million in 2002 to $200 million in 2004, according to New York City–based nanotech market research firm Lux Research. That means nanotech startups are finding it harder to do research in areas that could have tremendous long-range impact: new nanomaterials for optics and chip-cooling systems; biological diagnostics based on ultrasensitive nanosensors; and smart, automated delivery systems for protein drugs. "Over the years, the financial community has pushed for shorter-term results," says Peter Garcia, chief financial officer of Nanosys, a nanotech startup based in Palo Alto, CA. "There are projects that are more long term technically that have the greatest potential to change how products are made, but the funding is not there."

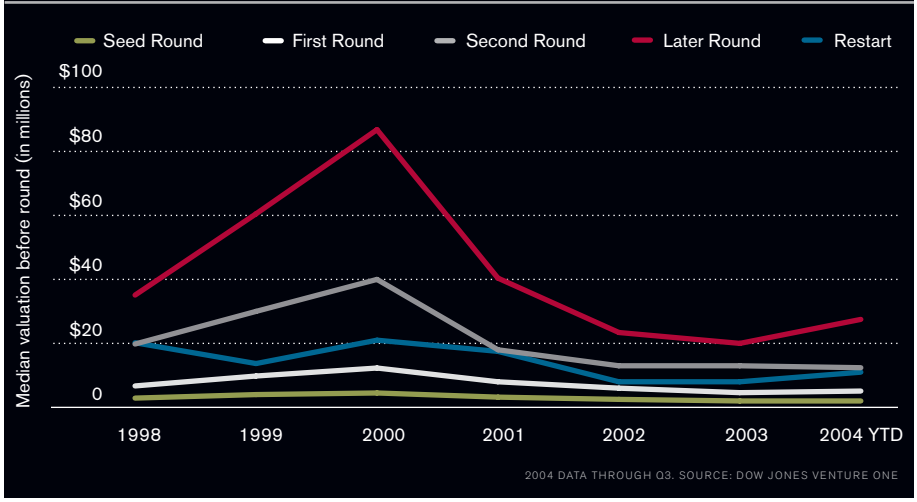
By contrast, areas of technology that require much less time in development are continuing to gain attention. One area that is attracting interest these days is RFID technology, which uses radio frequency identification tags that work like bar codes to track merchandise more precisely. The technology is hardly cutting edge; it has been ready for market for several years. But an international consortium has now established standards for RFID systems and is working with more than 30 companies to roll them out for large supply-chain management applications in the next year, creating lucrative opportunities for startups such as ThingMagic in Cambridge, MA, and Rockville, MD–based Matrics, which was acquired by Symbol Technologies for $230 million.

Other technology sectors finding favor with venture capitalists:

*Mobile applications:* entrepreneurs and venture capitalists are creating and funding companies that are developing new applications and services for cell phones, MP3 players, and other mobile devices; recent startups have concentrated on games, video, photo and music sharing, and location-based services. One example

## Valuing Maturity

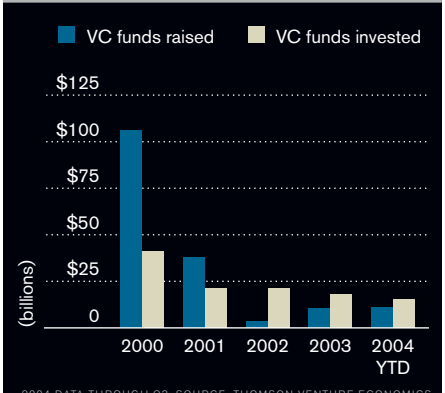
Valuations for VC-backed companies saw an uptick this year, driven mostly by gains among companies receiving their third round of funding or later (in red).




2004 DATA THROUGH Q3. SOURCE: DOW JONES VENTURE ONE

## Sitting on Billions

In recent years, the amount of venture capital invested has outstripped the amount raised. Still, more than $50 billion in venture capital raised since 2000 remains unspent.




2004 DATA THROUGH Q3. SOURCE: THOMSON VENTURE ECONOMICS AND THE NATIONAL VENTURE CAPITAL ASSOCIATION

is AudioFeast, which offers portable Internet radio service for MP3 players and mobile devices and raised $10 million in a recent round of financing.

*Business on the Internet:* the growing number of computers online and higher broadband penetration into households is helping business on the Internet to finally begin to fulfill its promise. And with Internet powerhouses like Google, Amazon, and Yahoo doing well, venture capitalists are feeling confident in Internet companies again. "Twenty-four months ago, they couldn't get any love from venture guys. Now they're beating down their door," says Tim Connors of U.S. Venture Partners. LinkedIn, a social-networking company in Mountain View, CA, secured $10 million in second-round financing in October; and Snocap, an online music copyright management company in San Francisco founded by the creator of Napster, got $10 million in December.

*Anything having to do with IT security:* though chief information officers are still on tight budgets, what money they are spending often goes to security. Viruses, worms, and spyware are on the rise, and entrepreneurs have leaped at the chance to make a buck off the fears they inspire. "It's an area that's been funded like crazy, but it's a problem that hasn't been solved," says Jeff Andrews of Atlas Ventures. Lending even more urgency to the development of security-related technology is the increase in government accounting regulations. Companies are under growing pressure to keep better track and control of all their documents, and they need new software and systems to do it. CIOs have no choice but to buy new technologies that enable them to comply with new government regulations.

*Biotech startups:* people will always get sick. Health-care costs continue to soar, and the drug pipeline remains constricted. So investors are turning to biotech, and especially to drugs for cancer, inflammation, and neurological and infectious diseases. Jazz Pharmaceuticals of Palo Alto secured last year's biggest venture capital financing round, $250 million, to commercialize drugs for neurological and psychiatric disorders. PharmAthene of Annapolis, MD, received $50 million in financing in October to develop therapeutics for bioterrorism agents.

# Public Markets

Google's hugely successful initial public offering last August was just the loudest demonstration that opportunities for IPOs are reviving after several years of dormancy. But while Google grabbed headlines and the attention of many investors, it is pharmaceutical and biotech companies that are actually dominating IPOs these days. Indeed, according to industry experts, IPO markets were particularly hospitable to biotech in 2004.

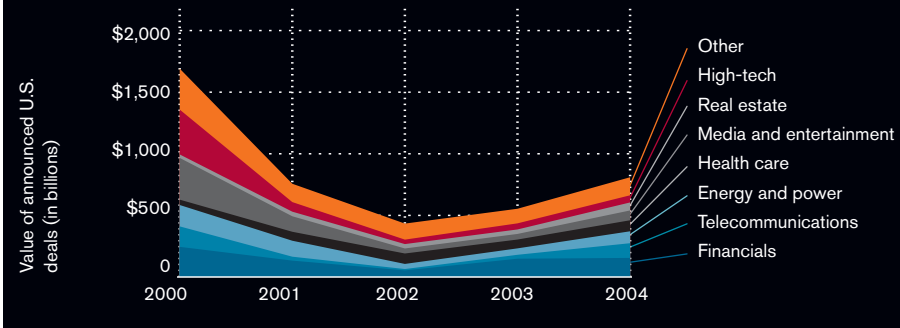
That trend is likely to continue. Steve Burrill, CEO of Burrill and Company, a life-sciences merchant bank, forecasts that some 30 to 40 biotechnology-related IPOs will occur in 2005, up from the 30 biotech IPOs in 2004. Burrill believes that, as pharmaceutical companies continue to have difficulty developing innovative new drugs, both they and the investment community have begun to recognize that innovations in life sciences are increasingly coming from the biotech sector.

Still, despite the current excitement over biotech, it *does* help for a startup to have a product before going public. Not surprisingly, it was companies with strong portfolios of products in the later stages of clinical testing whose stock fared best once it was publicly traded. When Eyetech Pharmaceuticals went public in January 2004, its drug for wet age-related macular degeneration (the leading cause of blindness in adults over 60) was well along in the drug development process. U.S. Food and Drug Administration approval came in December, and by year's end, the company had seen its IPO stock price of $21 a share double, leaving it with a market capitalization of $1.8 billion.

On the other hand, biotech companies with products still in initial, preclinical stages of testing are struggling—even startups with exciting technologies like Alnylam Pharmaceuticals, a company developing drugs that exploit a newly discovered molecular mechanism in the cell called RNA interference, which can be manipulated to shut down specific genes. [Disclosure: Robert Metcalfe, a general partner at Polaris Ventures, is an investor in Alnylam; Metcalfe also serves on the board of *Technology Review*.] Alnylam went public at the end of last May, hoping to raise $75 to $85 million at $10 to $12 a share. It ended up raising only about $30 million at $6 a share. According to Barry

## Momentum in Mergers

The pace of U.S. merger and acquisition deals increased significantly last year. Telecom mergers and acquisitions jumped 276 percent, from $32 billion to $119 billion.




AS OF DEC.27, 2004. SOURCE: THOMSON FINANCIAL

# Top Merger and Acquisition Deals

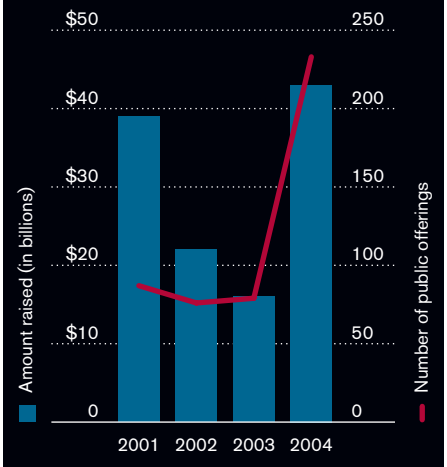
High-profile deals involving telecom, software, medical-device, and cable companies (in red) peppered the list of the largest U.S. mergers and acquisitions last year.

| Rank | Date announced | Target | Acquirer | Deal value (in billions) |
|---|---|---|---|---|
| 1 | 1/14 | Bank One | J. P. Morgan Chase | $58.8 |
| 2 | 2/17 | AT&T Wireless | Cingular Wireless | $41.0 |
| 3 | 12/15 | Nextel Communications | Sprint | $39.0 |
| 4 | 12/20 | Public Service Enterprise | Exelon | $27.4 |
| 5 | 12/15 | Guidant | Johnson and Johnson | $25.9 |
| 6 | 6/21 | SouthTrust | Wachovia | $14.2 |
| 7 | 11/17 | Sears Roebuck | Kmart | $13.8 |
| 8 | 8/20 | Rouse | General Growth Properties | $11.9 |
| 9 | 12/16 | Veritas Software | Symantec | $11.9 |
| 10 | 5/4 | Charter One | Citizens Financial Group | $10.5 |
| 11 | 12/13 | Oracle | PeopleSoft | $10.3 |
| 12 | 7/15 | Caesars Entertainment | Harrahs Entertainment | $10.2 |
| 13 | 8/2 | Cox Communications | Cox Enterprises | $8.4 |
| 14 | 6/4 | Mandalay Resort Group | MGM Mirage | $7.6 |
| 15 | 5/9 | National Commerce Financial | SunTrust Banks | $7.0 |

AS OF DEC. 27, 2004. SOURCE: THOMSON FINANCIAL AND NEWS REPORTS

# IPO Rebound

There were many more IPOs last year than in 2003, 2002, and 2001, but the total amount raised was only marginally greater than in 2001.




FOR THE NYSE, NASDAQ, AND AMEX EXCHANGES. SOURCE: HOOVER'S ONLINE

# The Best of 2004's IPOs

In the year of Google, an online-gaming company topped the list of best-performing IPOs.

| | Return at year's end | IPO date | Offer price | Last price of 2004 | Offering amount (in millions) | Description |
|---|---|---|---|---|---|---|
| Shanda Interactive Entertainment (NASDAQ: SNDA) | 286% | May 13 | $11.00 | $42.50 | $152 | Interactive-gaming network |
| Marchex (NASDAQ: MCHX) | 223% | March 31 | $6.50 | $21.00 | $26 | Performance-based advertising and search marketing services |
| Volterra Semiconductor (NASDAQ: VLTR) | 177% | July 30 | $8.00 | $22.16 | $50 | Low-voltage power supply chips |
| Cogent (NASDAQ: COGT) | 175% | Sept. 24 | $12.00 | $33.00 | $198 | Automated fingerprint identification |
| eCost.com (NASDAQ: ECST) | 175% | Aug. 27 | $5.80 | $15.95 | $20 | Online discount electronics |
| Syneron Medical (NASDAQ: ELOS) | 155% | Aug. 6 | $12.00 | $30.60 | $69 | Medical devices for skin |
| Kinetic Concepts (NYSE: KCI) | 154% | Feb. 24 | $30.00 | $76.30 | $540 | Specialized mattresses and medical devices |
| Kanbay International (NASDAQ: KBAY) | 141% | July 22 | $13 | $31.30 | $100 | Information technology services for financial-services firms |
| Valley Bancorp (NASDAQ: VLLY) | 137% | Sept. 23 | $18 | $42.69 | $15 | Las Vegas financial-holding company |
| RightNow Technologies (NASDAQ: RNOW) | 131% | Aug. 5 | $7.00 | $16.15 | $44 | Customer relationship management software and services |
| Atlas America (NASDAQ: ATLS) | 131% | May 11 | $15.50 | $35.75 | $36 | Appalachian natural-gas and oil production |
| Westlake Chemical (NYSE: WLK) | 130% | Aug. 11 | $14.50 | $33.40 | $200 | Petrochemicals and plastics |
| Google (NASDAQ: GOOG) | 127% | Aug. 19 | $85.00 | $192.79 | $1,666 | Search engine |
| Interchange Corporation (NASDAQ (SC): INCX) | 127% | Oct. 19 | $8.00 | $18.14 | $25 | Paid-search advertising |
| Bucyrus International (NASDAQ: BUCY) | 126% | July 22 | $18.00 | $40.64 | $183 | Replacement parts and services for the surface-mining industry |
| Eyetech Pharmaceuticals (NASDAQ: EYET) | 117% | Jan. 30 | $21.00 | $45.50 | $137 | Treatments for ocular conditions |
| WPT Enterprises (NASDAQ: WPTE) | 113% | Aug. 10 | $8.00 | $17.00 | $24 | Poker tournament producer |
| Navteq (NYSE: NVT) | 111% | Aug. 6 | $12.25 | $46.45 | $469 | Web-based mapping for vehicle navigation |
| AngioDynamics (NASDAQ: ANGO) | 101% | May 27 | $11.00 | $22.15 | $21 | Medical devices used to treat peripheral vascular disease |
| CoTherix (NASDAQ: CTRX) | 99% | Oct. 15 | $6.00 | $11.92 | $45 | Pulmonary treatments |

SOURCE: HOOVER'S ONLINE

Greene, the company's chief operating officer, part of the explanation for Alnylam's disappointing performance may be that it was the first biotech company in three years to go public without a compound in clinical trials. The lesson from biotech IPOs in 2004 was simple: although quite a number of companies were able to go public, investors remained cautious and gravitated toward companies with actual products that were ready for human testing. "The capital markets are very discriminating right now," says Greene.

One of the more anticipated events in the tech world turned out to be a nonevent. Or perhaps it was more of a reality check. Late last summer, Nanosys, a leading venture-backed nanotech company that is developing materials for electronics, withdrew the IPO it had planned for August 2004. [Disclosure: Robert Metcalfe is also an investor in Nanosys.] While some had hoped that the Nanosys IPO would open a window through which other nanotech startups might access the public markets, investors were clearly deterred by the Palo Alto company's warning that it would be several years, if ever, before it had any commercial products. Warren Packard of Draper Fisher Jurvetson, a venture capital firm known for investing in nanotech, says Nanosys made a smart business decision in pulling its IPO. The market isn't ready for nanotech, suggests Packard.

Most working in the field agree that the Nanosys decision simply confirmed that nanotech is still largely a research activity and is not ready for commercialization—something they have been saying all along. "Nanosys withdrawing its IPO was a short-term business decision on their part that really has no larger-scale impact on the field," says R. Stanley Williams, who leads Hewlett-Packard's effort in molecular electronics, one of industry's largest nanotech research programs. "They felt that because of the general level of enthusiasm [for nanotech], it might be a good idea to go early. They flew up a balloon and because of macroeconomic issues at the time, they realized they would not get the reception they hoped for. As far as I am concerned, it was no big deal, and people should not read too much into it."

What *is* a big deal is the resurgence of a sector once known as Internet stocks. According to a recent report by Mary Meeker—infamous for her new-economy cheerleading—and Brian Pitz at Morgan Stanley, a number of companies stand to cash in on a resurgence of e-commerce and other Internet businesses. Whether Meeker is correct this time around, the prospects of such companies—and the market success of Google, eBay, and others—are helping to spawn a new generation of Internet and desktop search companies and online auction houses. Desktop search has seen the rise of startups such as Copernic in Québec and Palo Alto–based Lookout, which was acquired by Microsoft last July.

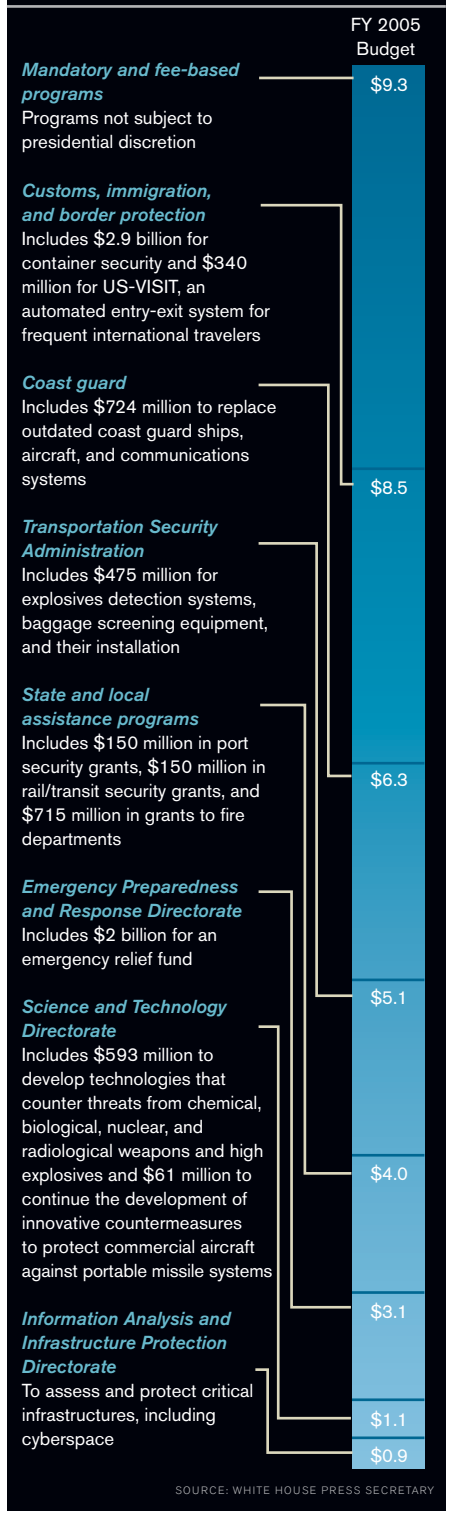
Other startup companies also made a huge splash in the public markets. Pasadena, CA–based Cogent, which develops automated fingerprint recognition systems used by law enforcement and the Department of Homeland Security, went public in September and raised $216 million, then saw its stock price nearly triple by the end of the year. And Shanda Interactive Entertainment, an Internet gaming company based in Shanghai, China, went public in May and saw its stock price increase almost fourfold.

# Government

While federal spending on defense and nondefense R&D has been approximately even for several years, the 2005 budget ends that parity, with defense spending now making up 56.7 percent of the federal R&D portfolio. The emphasis on defense R&D and homeland security will almost certainly mean a skewing of funding toward certain "hot" areas and to applied research. This year's budget, for example,

## Spending on Security

The U.S. Department of Homeland Security's discretionary budget increased by almost 7 percent in fiscal year 2005, to a total of about $30 billion.




SOURCE: WHITE HOUSE PRESS SECRETARY

will spend $8.8 billion for the further development of national missile defenses, up 15.8 percent.

Overall, Homeland Security's R&D budget increase of almost 20 percent was the biggest percentage jump among all the federal research agencies, according to analysis by the American Association for the Advancement of Science. Within this department, the Homeland Security Advanced Research Projects Agency (HSARPA) has been allocated a little more than $300 million a year; HSARPA's mission is to fund research at university and private labs, and it is mainly devoted to late-stage technologies that would be ready for market in three to five years, according to Vayl Oxford, the agency's acting director. A main area of funding is sensor technologies for biological, nuclear, and chemical warfare agents.

The increases in defense and security spending come at the expense of the research budgets at the National Science Foundation and at other non-defense-related agencies. Incoming NSF director Arden Bement saw his research budget for 2005 cut by .3 percent from the previous year. The cutbacks come just two years after a law was signed authorizing the doubling of the NSF budget between 2002 and 2007; indeed, NSF's budget had been on the rapid rise since 1998. But according to AAAS, the decrease in funding for 2005 will likely make doubling the budget just a pipe dream.

What the politicians are forgetting, say some technology experts, is that investing in basic research across a wide range of fields is also critically important to national security. "Our ability to respond [to an attack] is related to our innovative and technological capacity, and that depends mightily on the funding of basic research," says RPI's Jackson. She says she is most concerned about the cuts to the budget of NSF, because "it's the personification of support for basic research. It supports research across the broadest front, it's not specifically tied to a mission, and it supports education." Indeed, 80 percent of NSF's R&D money goes to colleges and universities, the highest percentage among all federal funding agencies.

**-3.9**

Percent change between NSF's requested and approved R&D budget

There are signs that cutbacks in non-defense-related research over recent years are already having an impact. Take robotics—a field in which the United States has traditionally been strong. "NSF really doesn't fund robotics anymore," says Alan Peters, a professor of electrical engineering at Vanderbilt University. The situation is worrisome enough that U.S. government agencies have formed a coalition of scientists to report to Congress on the state of American robotics research and funding this spring.

NIH, which over the last few years was the darling of Congressional appropriations committees (enjoying 15 percent annual increases from 1998 to 2003), has had its funding growth grind almost to a halt. In 2004, the total NIH budget increased by 2 percent, the smallest increase in decades, and much of that was allocated to research on biodefense, where spending rose by 3.8 percent to $1.7 billion. As recently as three years ago, NIH funding for biodefense was $162 million. Another notable casualty of the 2005 federal budget was the Advanced Technology Program (ATP) at the National Institute of Standards and Technology. Established to help support startup companies developing innovative but early-stage technologies, the ATP program has long been the target of the Republican administration. And while President Bush failed in his attempt to axe the program this year, the final 2005 budget did slash ATP's funding to $136 million, a 24 percent decrease from 2004.

## Defense Gets the Money

The federal R&D budgets for the National Science Foundation, NASA, and the Department of Health and Human Services received slightly less than requested for the 2005 fiscal year.

| | *FY 2005 request (millions)* | *FY 2005 approved (millions)* | *Percent change from request to approval* | *Percent change from FY 2004* |
|---|---|---|---|---|
| Defense | $68,759 | $70,285 | 2.2% | 7.1% |
| Health and Human Services | $29,361 | $29,108 | -0.9% | 2.2% |
| National Aeronautics and Space Administration | $11,334 | $11,132 | -1.8% | 2.0% |
| Energy | $8,880 | $8,956 | 0.9% | 1.7% |
| National Science Foundation | $4,226 | $4,063 | -3.9% | -0.3% |
| Agriculture | $2,163 | $2,414 | 11.6% | 7.8% |
| Homeland Security | $1,141 | $1,243 | 8.9% | 19.9% |
| Commerce | $1,075 | $1,183 | 10.0% | 4.6% |
| Department of Veterans Affairs | $770 | $813 | 5.6% | -0.8% |
| Transportation | $755 | $718 | -4.9% | 1.5% |
| Interior | $648 | $672 | 3.7% | -0.5% |
| Environmental Protection Agency | $572 | $598 | 4.5% | -2.8% |
| Education | $304 | $258 | -15.1% | -11.1% |
| Agency for International Development | $223 | $243 | 9.0% | 2.1% |
| Smithsonian | $144 | $141 | -2.1% | 3.8% |
| Nuclear Regulatory Commission | $61 | $61 | 0.0% | 0.9% |
| *All other* | *$302* | *$311* | *3.0%* | *-0.2%* |
| Total R&D | $130,717 | $132,200 | 1.1% | 4.8% |

SOURCE: AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

# Licensing and Patenting

More-concentrated funding of select sectors and an emphasis on later-stage technologies are also dominant trends in the world of intellectual property and licensing. At many of the nation's leading research universities and institutes, licensing deals with industry have grown fewer in number and more conservative in nature. Industry doesn't seem to be as interested in fundamental breakthrough technologies in areas such as nanotech; instead it favors more short-term and less risky technologies that are closer to commercialization and have clear markets and customers, says Katharine Ku, director of Stanford University's technology licensing office.

Over the past two years, companies licensing technology from universities have begun to favor later-stage deals involving technologies that are far enough along to be deemed marketable. And small companies are buying—or in the case of university spinoffs, teaming with academia to create—a larger proportion of intellectual property relative to larger corporations. Even at Caltech, one of the world's leading centers of technology and research, "we've had to be more creative about where to raise money for early-stage spinout companies," says Rich Wolf, director of the Caltech technology licensing office.

But there is hope that these trends are beginning to turn around. "This is a cyclical thing," says MIT's Lita Nelsen, who has worked in technology licensing since 1986. "We are beginning to see more folks realize there's not much money in late-stage deals, so let's look at early stage." In particular, Nelsen has noticed a dramatically increased interest in technologies, even early-stage ones, related to security. "The rumor mill says that on the West Coast, they're funding anything with 'security' in it," she says. "Anything from detecting bombs to hacking computers." And though many such technologies, such as new kinds of computer-virus detectors, are scheduled for deployment in the next year, others are part of longer-term projects to develop more-sensitive biohazard detectors and intelligent sensor networks.

It's not only areas of technology that are being funded unequally; it's also institutions. While perennial powerhouses like the University of California system, MIT, and Stanford are doing quite well in the tech licensing realm, other schools, even some large state schools, still fight to generate revenue. For example, the University of Texas at Austin is actively trying to spin off more companies, rather than licensing technologies to existing companies. "We are aggressively doing startups," says Neil Iscoe, director of the University of Texas's office of technology licensing. "We have to change our approach to get more things out," he adds. "How do you market a disruptive technology? You do it through a startup."

And overall, say some, it seems both companies and universities are developing a more realistic view of which technologies are useful and what they're worth. "During the bubble years...university licensing people thought that any idea at all was worth mega- or giga-bucks. In fact, we have an easier time to work with academics now, since reality has set in," says Hewlett-Packard's Williams. That means academics should be able to focus more on science and getting new technologies to the state at which companies can develop and market them. ■

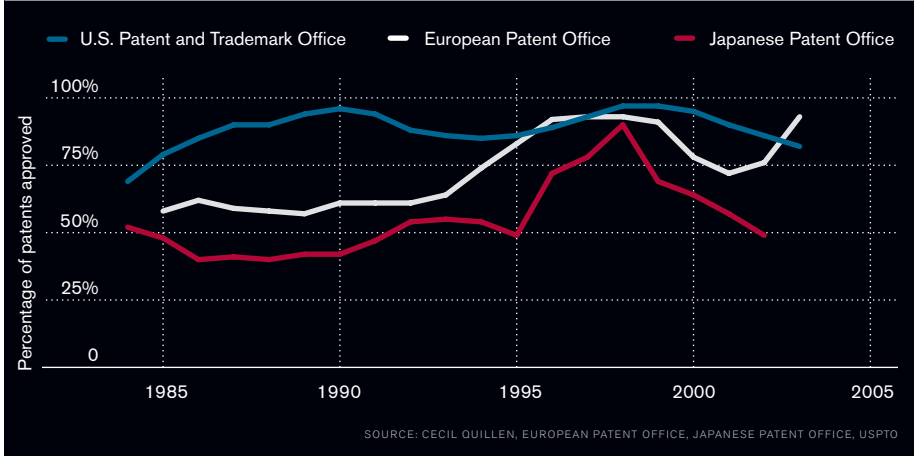
*Technology Review editors Gregory T. Huang, Corie Lok, and David Rotman contributed to this report.*

**82**

Percentage of U.S. patent applications that are approved

## U.S. Patent Approvals Dip

Some 82 percent of U.S. patent applications reviewed in 2003 were approved, a much smaller portion than in the late 1990s.




SOURCE: CECIL QUILLEN, EUROPEAN PATENT OFFICE, JAPANESE PATENT OFFICE, USPTO

# The Elite in Patenting and Licensing

The U.S. research institutions that patent the most are not necessarily the ones to glean the most revenue from licenses to private companies.

Top U.S. research institutions by the number of patents issued in 2003

| | U.S. patents issued | New U.S. patent applications filed | Invention disclosures received | Licenses executed in 2003 | License income received in 2003 (in millions) | Total number of income-generating licenses | Startups formed | Year tech transfer office inititated | Total research expenditures (in millions) |
|---|---|---|---|---|---|---|---|---|---|
| University of California system | 323 | 490 | 1,027 | 208 | $67.0 | 826 | 22 | 1979 | $2,623.3 |
| California Institute of Technology | 169 | 207 | 504 | 39 | $25.4 | 71 | 7 | 1978 | $367.0 |
| MIT | 152 | 235 | 452 | 114 | $26.8 | 379 | 15 | 1940 | $994.4 |
| Stanford University | 117 | 290 | 362 | 128 | $45.4 | 377 | 12 | 1970 | $639.9 |
| Johns Hopkins University | 95 | 380 | 330 | 159 | $6.7 | 218 | 5 | 1973 | $1,461.6 |
| University of Wisconsin-Madison | 87 | 146 | 406 | 177 | $37.8 | 245 | 0 | 1925 | $721.2 |
| Massachusetts General Hospital | 85 | 105 | 199 | 62 | $46.0 | 106 | 4 | 1976 | $409.5 |
| Mayo Foundation for Medical Education and Research | 69 | 58 | 226 | 133 | $11.1 | 254 | 0 | 1986 | $351.0 |
| University of Chicago | 67 | 67 | 99 | 21 | $4.3 | 58 | 0 | 1986 | $294.1 |
| University of Michigan | 64 | 97 | 257 | 76 | $9.1 | 177 | 9 | 1982 | $749.3 |

Top U.S. research institutions by the amount of license income received

| | License income received in 2003 (in millions) | Licenses executed in 2003 | Total number of income-generating licenses | Invention disclosures received | New U.S. patent applications filed | U.S. patents issued | Startups formed | Year tech transfer office inititated | Total research expenditures (in millions) |
|---|---|---|---|---|---|---|---|---|---|
| New York University | $85.9 | 24 | 47 | 93 | 63 | 21 | 4 | 1989 | $225 |
| Sloan Kettering Institute for Cancer Research | $74.1 | 29 | 61 | 74 | 33 | 34 | 0 | 1981 | $224 |
| Research Corporation Technologies | $71.4 | 43 | 240 | 155 | 3 | 7 | 0 | 1987 | N/A |
| University of California system | $67.0 | 208 | 826 | 1,027 | 490 | 323 | 22 | 1979 | $2,623 |
| New York Blood Center | $60.0 | 7 | 2 | 4 | 2 | 5 | | 1975 | $15 |
| City of Hope National Medical Center annd Beckman Research | $55.9 | 5 | 27 | 13 | 18 | 16 | 0 | 1986 | $108 |
| Massachusetts General Hospital | $46.0 | 62 | 106 | 199 | 105 | 85 | 4 | 1976 | $409 |
| Stanford University | $45.4 | 128 | 377 | 362 | 290 | 117 | 12 | 1970 | $640 |
| University of Minnesota | $38.1 | 56 | 210 | 218 | 72 | 54 | 4 | 1957 | $509 |
| University of Wisconsin-Madison | $37.8 | 177 | 245 | 406 | 146 | 87 | 0 | 1925 | $721 |

SOURCE: ASSOCIATION OF UNIVERSITY TECHNOLOGY MANAGERS

# Introducing the *Technology Review* Index

## Keeping an eye on business

TECHNOLOGY REVIEW, of course, is all about the future, and the companies and people involved in the innovation that will get us there. It is in that spirit that we introduce the *Technology Review* Index, which includes the *TR* Large-Cap 100 and its sibling, the *TR* Small-Cap 50. Developed in conjunction with Standard and Poor's, these global equity indices will serve as our own in-house gauge of the pulse of innovation at 150 of the world's most important public companies.

Our two indices will track both the most powerful innovators and the up-and-comers in the 10 most innovative industries of the global economy. The performance of these indices will be updated daily on our online platform at www.technologyreview.com/TRIndex.

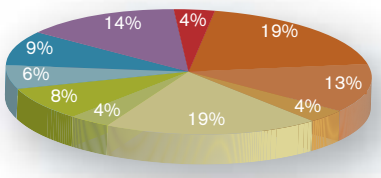
Each month, the editors of the magazine will discuss the performance of the *Technology Review* indices, their constituent industries, and any of their component stocks that stand out in particular. This review should, we think, provide an invaluable reference point for those with a stake in innovation—both today and in the future.

DUFF MCDONALD

| | TR Large-Cap 100 | TR Small-Cap 50 |
|---|---|---|
| Number of companies | 100 | 50 |
| Total market cap (in millions) | $5,849,999 | $93,979 |
| Average company size (in millions) | $58,500 | $1,880 |
| Largest (in millions) | $321,210 | $2,876 |
| Smallest (in millions) | $9,643 | $574 |
| Largest company's percentage of total market cap | 5.5% | 3.1% |
| Market cap of top 10 companies | 39.9% | 26.4% |

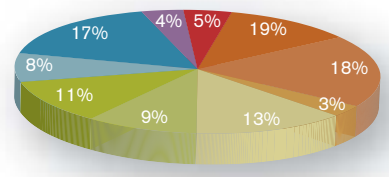
## *Technology Review* Large-Cap 100, industry breakdown by market capitalization

| Industry | Number of companies | Total market cap (millions) | Average market cap (millions) |
|---|---|---|---|
| Aerospace and defense | 8 | $216,236 | $27,029 |
| Biotech and pharmaceuticals | 11 | $1,136,760 | $103,342 |
| Computers | 11 | $755,491 | $68,681 |
| Consumer | 7 | $210,416 | $30,059 |
| Energy | 9 | $1,119,829 | $124,425 |
| Health care | 9 | $211,972 | $23,552 |
| Media | 14 | $487,481 | $34,820 |
| Semiconductors and equipment | 10 | $358,553 | $35,855 |
| Software and services | 8 | $534,486 | $66,811 |
| Telecommunications services | 13 | $818,776 | $62,983 |




## *Technology Review* Small-Cap 50, industry breakdown by market capitalization

| Industry | Number of companies | Total market cap (millions) | Average market cap (millions) |
|---|---|---|---|
| Aerospace and defense | 2 | $4,289 | $2,145 |
| Biotech and pharmaceuticals | 6 | $11,089 | $1,848 |
| Computers | 10 | $17,690 | $1,769 |
| Consumer | 4 | $2,936 | $734 |
| Energy | 5 | $12,334 | $2,467 |
| Health care | 4 | $8,917 | $2,229 |
| Media | 5 | $10,162 | $2,032 |
| Semiconductors and equipment | 4 | $7,232 | $1,808 |
| Software and services | 8 | $15,931 | $1,991 |
| Telecommunications services | 2 | $3,398 | $1,699 |




## *TR* Large-Cap 100 top five companies

| Country | Name (ticker) | Market cap (millions) | Index weight | Industry weight | Industry |
|---|---|---|---|---|---|
| USA | Exxon Mobil (XOM) | $321,210 | 5.5% | 28.7% | Energy |
| USA | Microsoft (MSFT) | $289,945 | 5.0% | 54.2% | Software and services |
| UK | BP (BP/LN) | $204,143 | 3.5% | 18.2% | Energy |
| USA | Pfizer (PFE) | $198,065 | 3.4% | 17.4% | Biotech and pharma |
| USA | Johnson and Johnson (JNJ) | $185,809 | 3.2% | 16.3% | Biotech and pharma |

## *TR* Small-Cap 50 top five companies

| Country | Name (ticker) | Market cap (millions) | Index weight | Industry weight | Industry |
|---|---|---|---|---|---|
| USA | Cooper Companies (COO) | 2,876 | 3.1% | 32.2% | Health care |
| Canada | First Calgary Petroleums (FCP) | 2,756 | 2.9% | 22.3% | Energy |
| USA | Varco International (VRC) | 2,692 | 2.9% | 21.8% | Energy |
| USA | Patina Oil & Gas (POG) | 2,582 | 2.7% | 20.9% | Energy |
| USA | Cree (CREE) | 2,482 | 2.6% | 34.3% | Semiconductors and equipment |

SOURCES: STANDARD AND POOR'S CUSTOM INDEX SERVICES, *TECHNOLOGY REVIEW*

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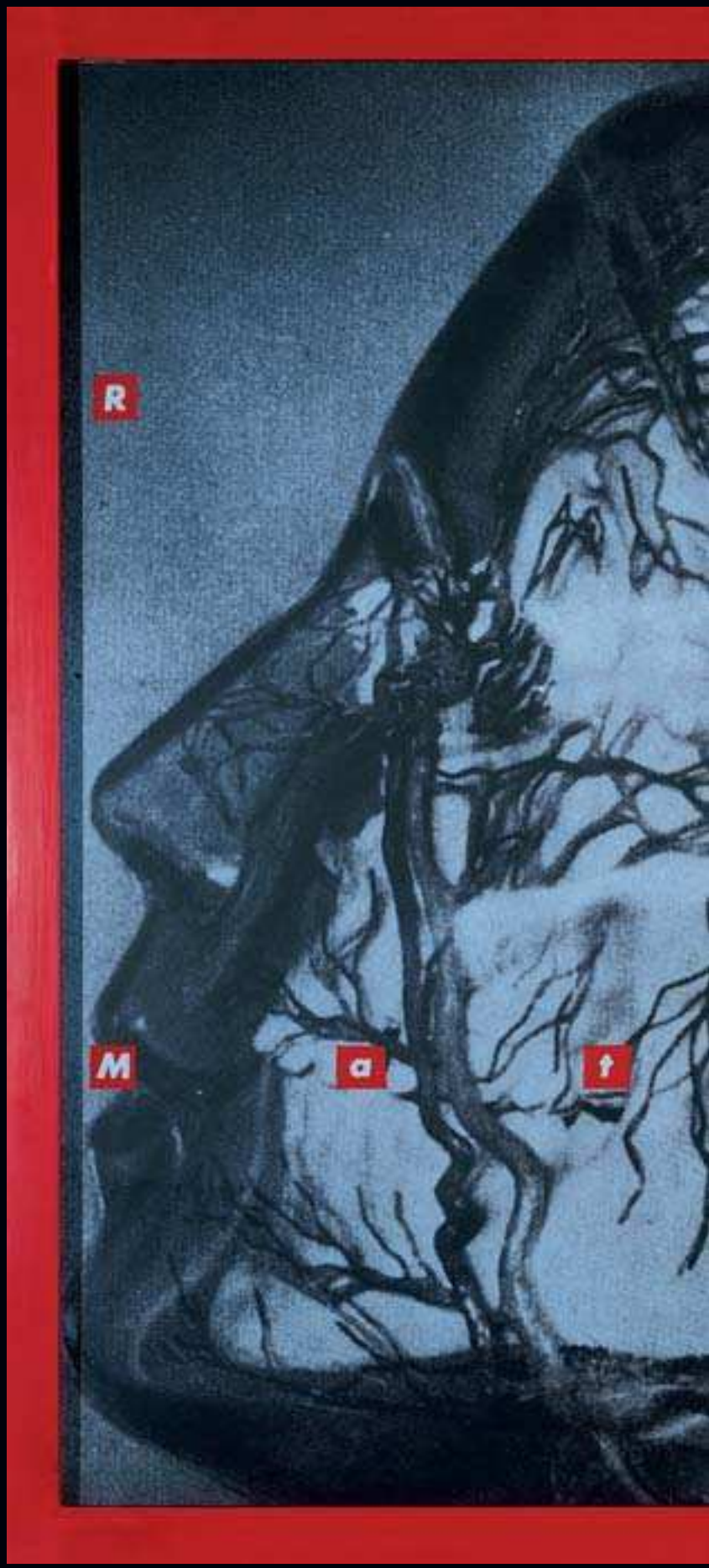
# *Implanting Hope*

## *For the first time, a paralyzed patient has operated a prosthetic arm using just his mind.*

By David Ewing Duncan




**SNAP, CRACKLE, POP.** I'm listening to a brain talking in a language that seems unintelligible, a chorus of millions of neurons firing, sounding to my ear like the electrical fuzz of a shortwave radio between stations. Then comes a distinctive "pop." I hear it again: "pop." I am watching a video. The brain in question belongs to a bearded man sitting in a chair. The victim of a stabbing three and a half years ago, he is paralyzed from the neck down. The ventilator that allows him to breathe is gurgling. Matthew Nagle, a 25-year-old former high-school football star from Weymouth, MA, has a round, titanium pedestal protruding half an inch from his head on the right side near the crown. ■ On July 4, 2001, Nagle became involved in a melee at Wessagussett Beach in Weymouth. He remembers only that fists began to fly and that a friend was under attack. Someone shouted something about a knife, and Nagle blacked out. Later that night, when his father, a police detective, got a call from the police, he was told that his son would probably die. The 20-centimeter blade had severed the spine in his neck, leaving him paralyzed and on a respirator. Nagle survived, but after years of immobility and tedium, he agreed to take part in a clinical trial to determine whether or not a human could safely manipulate a


Barbara Kruger, *Untitled*, Mary Boone Gallery

computer cursor using a brain-computer interface (BCI).

Attached to the pedestal, surgically implanted beneath Nagle's skull, is an array of electrodes on a chip contiguous to the part of his brain that controls motor activity. The chip is the size of a baby aspirin: its 100 tiny hair-thin electrodes pick up the electrical signals transmitted by the brain, each electrode capturing signals from a few nearby neurons. As demonstrated in a video I watched late last year, a square, gray plug is screwed onto the pedestal; the plug is attached by wires to a nearby computer. When Nagle's neurons fire, the impulses are read and decoded by software that can interpret the electrical pops of sets of neurons. The computer reads Nagle's thoughts—or at least the pops recorded by the electrodes—and deciphers a few simple commands spoken in the electrical language of the brain.

Nagle sits in front of a prosthetic hand. Originally designed for amputees who would control it by twitching muscles in the stumps of their arms, the robotic limb has been hooked up to the computer and will open and shut when Nagle imagines that he is opening and closing his own left hand. Nagle may be paralyzed, but the neurons in his cerebrum that control motor activity are quite healthy.

Snap, crackle, pop.

I hear a technician ask Nagle to imagine using his hand. He does. This fires up the relevant neurons in his motor cortex, creating an electrical signal that is received by the implanted electrodes and decoded by the computer—a series of events that causes the artificial thumb and forefinger to open and close.

The implications for Nagle and others like him, trapped inside malfunctioning bodies by injuries or degenerative neurological diseases, are wonderful. Nagle is the first human ever to operate a prosthetic arm with only his mind. During a visit to his room at an assisted-care facility south of Boston, I further observed Nagle operate a cursor on a computer that allows him to send and receive e-mails, play simple games, and control his television. Surrounded by photographs of his friends and family, and by his veritable shrine to the Boston Red Sox and their 2004 victory in the World Series, Nagle worked with technician Maryam Saleh as she calibrated the computer to his brain. The setup is bulky, about the size of a washing machine, with two monitors for the technician and one for Nagle.

When I saw him, Nagle was tired and a bit cranky, his handling of the cursor rudimentary. He attempted to catch an animation of a small bag of money with the cursor. "I can't get it today, not even close," he complained.

**For now, the technology is very crude. The computer understands only a tiny fraction of what goes on in Nagle's brain.**

Later, Saleh set up the computer so that Nagle could change channels on a television, and with effort Nagle was able to switch the channel. The presence of a reporter may have been part of the problem that day. The scientist chiefly responsible for Nagle's device, neuroscientist John Donoghue of Brown University, assured me that his patient had done much better in the past. Nagle told me that the day before my visit, he had successfully manipulated a more advanced prosthetic arm with joints that enabled humanlike movements. "It worked really well," says Nagle. "I could move it all around."

"It's encouraging that the system has worked this well," says Leigh Hochberg, a Harvard University neurologist and an expert on patients with severe motor impairments. Hochberg is a principal investigator for the U.S. Food and Drug Administration trial approved in April of last year to test the implants on five patients. (So far, Nagle is the only volunteer for the trial.)

For now, the technology is very crude. The computer understands only a tiny fraction of what goes on in Nagle's brain, where billions of neurons can be firing at any one time, with trillions of interactions. Still, the implant is a significant step, a neurological Rosetta stone in the most complex deciphering project in history, one that might not be completed for decades, if ever.

### A First Step

Nagle is not the first human to operate an implanted BCI. In the late 1990s, neuroscientist Philip Kennedy, the cofounder and chief executive of an Atlanta-based neuro-prosthetics company, Neural Signals, implanted electrodes in the brains of patients. But Kennedy implanted only two glass electrodes, so far fewer neural signals were picked up than is possible with Nagle's array. Kennedy's subjects could only move a cursor up and down on a computer screen. Donoghue hopes to make the technology much more functional. In addition to being a professor of neuroscience at Brown, Donoghue is the cofounder and chief scientific officer of Cyberkinetics Neurotechnology Systems of Foxborough, MA, which owns the technology and is running the trial. Cyberkinetics hopes to sell its Braingate Neural Interface System within five years to patients suffering from quadriplegia and other debilitating conditions, including some types of stroke and amyotrophic lateral sclerosis (Lou Gehrig's disease), says company president and CEO Timothy Surgenor. Surgenor envisions a version of Braingate that would allow patients, with the power of thought alone, to control wheelchairs outfitted with artificial arms and hands, close the blinds in a sunny room, and perform other similar tasks.

The idea of starting a company came to Donoghue in 2000 during a conversation with postdoc Nicholas Hatsopoulos. Originally, says Hatsopoulos, who is now an assistant professor of neuroanatomy at the University of Chicago, the research was solely to study how neurons control movements in monkeys. Then, one day in a hallway in the lab, Donoghue said, "Why don't we start a company and take this to humans?" Hatsopoulos readily agreed. Since its founding in May 2001, Cyberkinetics has raised more than $15 million and spent about $10 million, and it will need $40 million to $50 million more to keep operating over the next three to five years, until Braingate is approved and can be sold. The device must still be streamlined and made wireless,

Surgenor says, and automated so that Nagle and others can use it on their own.

The scientists collaborating with Donoghue at Brown and Cyberkinetics are among the many around the world working on the next generation of neural prosthetics—that is, prosthetic devices animated by human thought alone. Donoghue says this research may one day allow the disabled to walk, and it will perhaps permit Nagle to use his own hands again, by supplementing a damaged, organic nervous system with a functional cybernetic system. Such claims would have seemed fanciful just a few years ago, but other scientists find them plausible. "It's a very strong possibility that we can do this," says University of Pittsburgh neuroscientist Andrew Schwartz.

At the same time, however, Schwartz is skeptical that Donoghue's current device works as well as advertised. "The movements they're getting are crude," he says. "It's not clear how good the human recordings [of the neural signals] are; they haven't told us this yet." Schwartz also wonders if playing games, sending e-mail, and turning on the television will really improve the patient's quality of life unless the patient is "shut in"—that is, so totally paralyzed that he or she can neither talk nor blink and is thus unable to use computer interfaces that are voice and eye activated. "To be useful, it will have to be much better, to do more things," he says. Schwartz's own lab has developed a BCI for monkeys that moves an arm with humanlike range and dexterity in a three-dimensional space.

Neuroscientist Miguel Nicolelis of Duke University, another expert in the field of BCI, dismisses the Nagle trial as a "stunt." "There are other prosthetic devices and interfaces that can do these things," he says. "To go with surgical intervention, you need to do something more profound. I think they skipped a couple of steps to make this ready for humans." The electrodes, for instance, are susceptible to clogging with organic matter, he says. Indeed, to work properly, Nagle's implant may have to be surgically replaced periodically. Nicolelis worries about setbacks for the field if something goes wrong, like an infection following surgery. Nicolelis plans to implant his own sensors in humans in the near future, but only for the purposes of academic research. He is critical of Cyberkinetics' commercial motivations: he fears that the company is more concerned about cash and promoting its work than about delivering the greatest benefit to patients.

JOSHUA PAUL

**Matthew Nagle, who was paralyzed in 2001, volunteered to help test a new brain-computer interface developed at Brown University.**

Other neuroscientists support Donoghue. "I think the time has come to do this in humans," says Richard Andersen, a leading neuroscientist at the California Institute of Technology who is also about to conduct human research using implanted electrode devices developed by his lab. Neuroscientist Bill Heetderks, who headed the neural-prosthetics programs at the National Institute of Neurological Disorders and Stroke until 2003 and oversaw grants to Donoghue, Nicole-

lis, and other major researchers, points out that the FDA approved the Cyberkinetics trials as safe and promising. He says that Donoghue's experiments have answered a crucial question that could not have been addressed in an animal study: would human motor neurons still fire up as they would in a healthy person after prolonged paralysis of the limbs? "This was an important reason to do this experiment in a human," he says. "Now we know the cells still work."

Donoghue says that every precaution is being taken to protect patients but agrees that Nagle is not able to execute commands very ably. "It's not like an able-bodied person controlling a mouse," he says he argues that even a limited ability is better than none for a quadriplegic.

To potential critics of Braingate, Nagle says, "Have them come down and take a look." Glancing at his room and his motionless body, Nagle says, "This is my life. I volunteered to do this."

Nagle says that Braingate is of limited help to him now because he can use it only when the technician is there, and it must be recalibrated each time. "Hey, I want to walk again, or to be able to use this to operate my wheelchair. But this is a first step." Asked whether he thinks that Cyberkinetics might have rushed to early trials because of its commercial ambitions, Nagle says he's not bothered. "I think they needed this to get funding, and thank God they got the funding. If they can [help me] make this wheelchair go and sell [that capability to others], then I'm all for it."

## Reading Intent

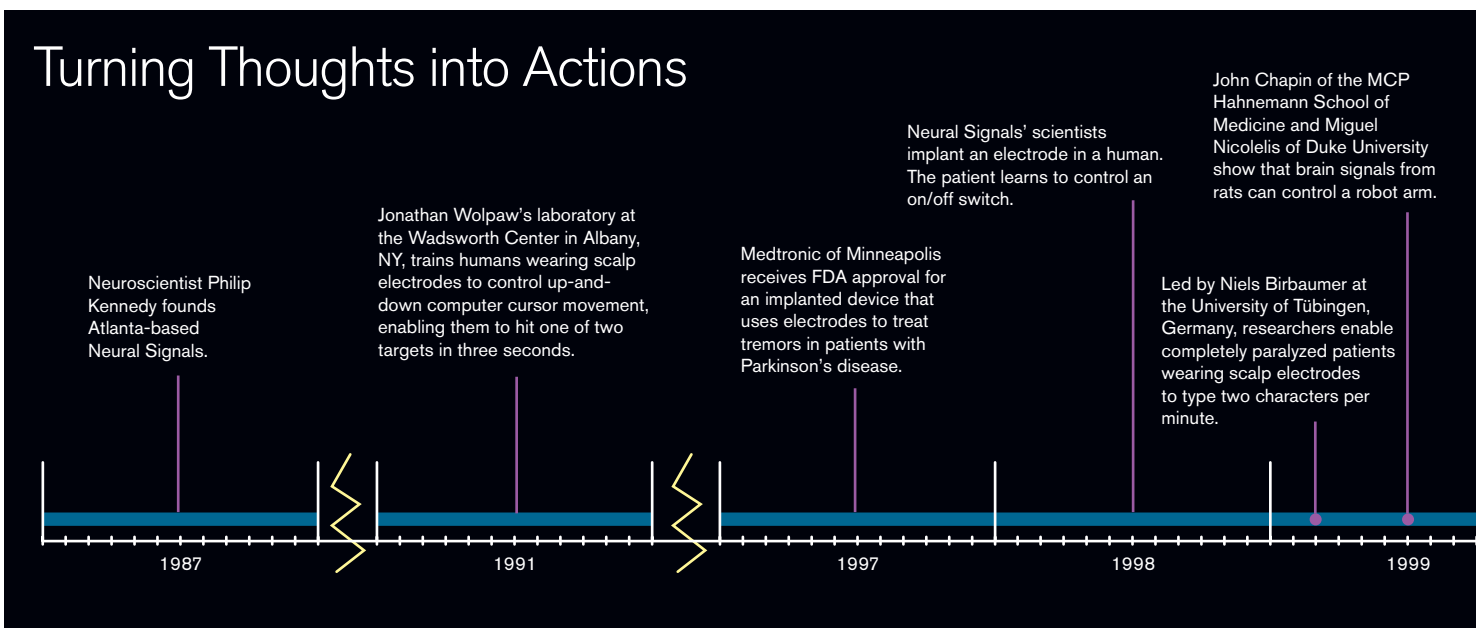
Donoghue's work is best understood in the context of the scientific effort to interpret and act on neuronal activity. Some scientists, like Donoghue, want to implant electrodes to capture more neuronal data more quickly; others are not sure implants are necessary. But all share an interest in understanding how the brain might work with a computer to create practical technologies for a range of purposes.

The words of the neuronal language can be heard in the electrical "spikes" in neurons—although some neuroscientists have proposed creating a BCI by monitoring broader, deeper "fields" of brain activity using electroencephalography, which would not require the surgical implantation of electrodes. EEG sensors have had some success, but they have produced only faint signals compared to implants that capture neuronal spikes.

A spike is the pinnacle of an electrical surge, the "action potential" that occurs when a neuron is activated and fires. On one of the monitors showing Nagle's brain activity, dozens of action potentials play out in rows across the screen as the computer compiles signals from the electrodes in Nagle's implant, each of which registers the activity of dozens of neurons. When a neuron fires, the line on the monitor begins to rise in proportion to the electrical surge, and then, moving at a speed more than 100 times faster than the blink of an eye, it peaks, which is what causes the "pop." Once the neuron has fired, its electrical signal drops back down, and the output either stays flat or begins its ascent again. Neurons, when active, fire between 20 and 200 times a second. The timing and the location of spikes in the brain, and the interaction of multiple spikes among neurons, create the coherent signals that are turned into muscle movements and all the other "outputs" of the brain.

"Understanding how groupings of neurons work for motor activity is relatively simple," says Hatsopoulos, who helped write the algorithms for Braingate. "As we learn to read more neurons at once, it will eventually tell us how higher brain functions work, such as emotions and other behavior and thought processes."

By conducting human trials, Donoghue has pulled ahead of his colleagues, though other scientists have plans for their own clinical trials of neuro-prostheses controlled with implanted electrodes. In Atlanta, Kennedy's company has received approval from the FDA to test single- and double-electrode implants in severely disabled patients. At Caltech, Andersen's team has begun to experiment on humans suffering from epilepsy, using brain implants surgically embedded in the prefrontal cortex (an area that helps plan and execute bodily movement); the implants



sense an oncoming seizure and apply tiny electrical shocks to shut it down. Though Andersen has no commercial plans for the device, he intends to expand the human tests in clinical trials.

Andersen is also expanding his work with monkeys; he has implanted sensors in the higher-functioning areas of a monkey's brain and deciphered some of the electrical signals whereby the monkey plans actions and others that seem to govern its motivation to perform a specific feat. "We have a difference in approach from Donoghue's work," says Andersen. "We're reading intent"—whereas Donoghue is tapping into the motor-action part of the brain. Monkeys with electrodes in either brain region can move cursors and devices, says Andersen.

Duke's Nicolelis has invented a system that allows a monkey to move a prosthetic arm up and down to deliver a snack. Nicolelis also linked up his monkey's brain to the Internet and had the monkey operate a robot arm 950 kilometers away. He has been testing humans with deep brain implants to study the patterns in which their neurons fire when they squeeze balls. So far, he has recorded the output of up to 50 cells and is using this electrical data to devise algorithms to move a cursor. He is also studying how neurons in the brain adapt to the use of robotic arms and machines, since neurons are continually modified by the acquisition of new information and skills.

These types of experiments are rapidly advancing the technology, giving it more and more potential to help patients. At the University of Pittsburgh, Schwartz has run experiments enabling monkeys to move an artificial arm and hand more fluidly. "These devices have the degrees of motion of a human arm and elbow," he says. His team wants to test their arm on humans. "We're on a five-year horizon," Schwartz says, for the arm to be working well in humans.

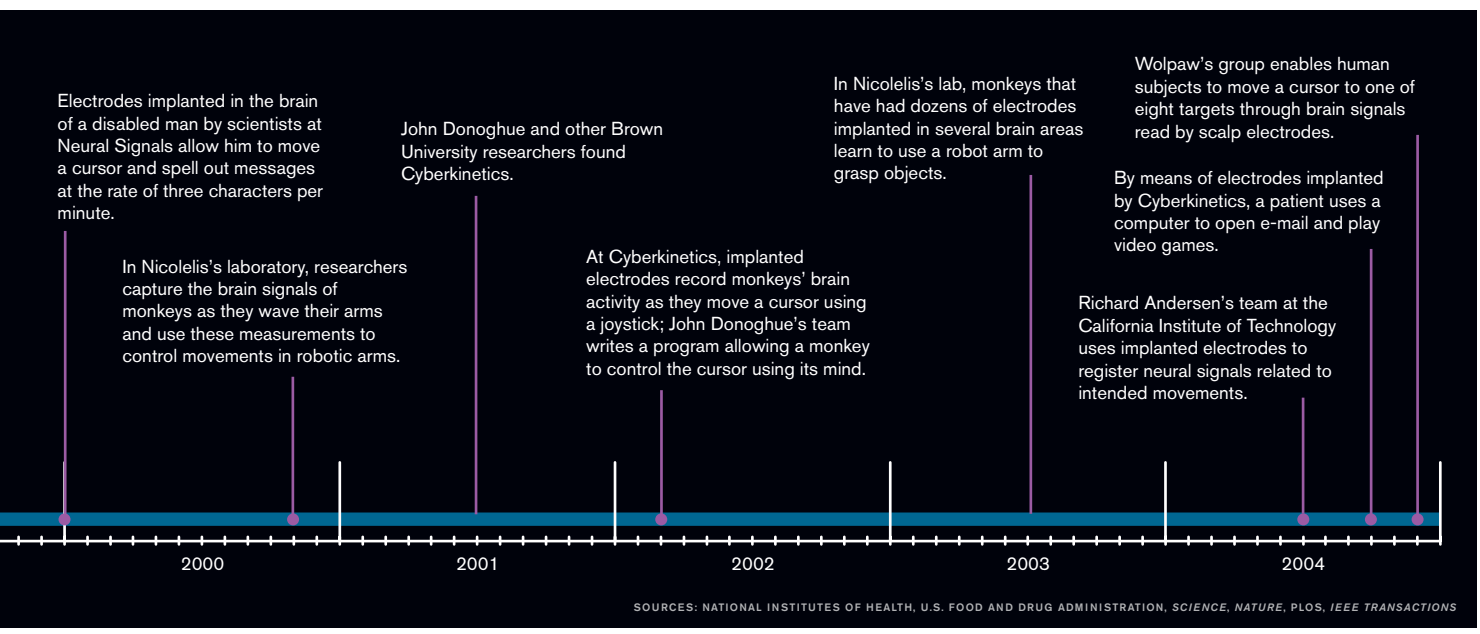
**Nagle was soon able, with practice, to draw a crude circle on the screen with his mind, and he progressed to playing Pong.**

### Ping! Pong!

Brown neurosurgeon Gerhard Friehs performed Nagle's implant operation at Rhode Island Hospital in Providence in June 2004. Friehs is an expert at implanting neuro-devices such as the Activa brain stimulators for Parkinson's patients that control the muscle tremors associated with the disease. On a plastic model, Friehs showed me the spot where he drilled a small hole into Nagle's skull, above the region that controls the left arm. Friehs then inserted the implant using a pneumatic inserter, a device he says is like a staple gun that shoots the electrode array onto the brain.

Nagle was first put under general anesthesia, though Friehs says that in the future, this may not be necessary. Technicians then used magnetic-resonance imaging (MRI) of Nagle's brain to pinpoint the motor cortex area specific to his anatomy. In the operating room, Friehs used the MRI data to guide him to the precise coördinates in Nagle's brain and then revved up a high-speed drill to remove a half-dollar-sized circle of skull. Friehs inserted the four-by-four-millimeter electrode chip, the wires, and the pedestal and replaced the piece of skull. Total operating time: about four hours.

Six weeks later, after Nagle's wounds had healed and the immediate threat of infection was past, the researchers prepared to test Braingate. Cybernetic's technician Abraham Caplan, who makes the house calls with Saleh to operate Braingate two or three times a week at the assisted-living center where Nagle lives, remembers the first time they plugged in Nagle, in August 2004. On the video of this inaugural experiment, Nagle is sitting




SOURCES: NATIONAL INSTITUTES OF HEALTH, U.S. FOOD AND DRUG ADMINISTRATION, *SCIENCE*, *NATURE*, PLOS, *IEEE TRANSACTIONS*

in his chair, and Saleh asks him to imagine moving his hand to the left. The computer broadcasts the snaps and pops of the signals that race across its screen, as it reads the brain's real-time chatter, which it correctly translates into a cursor moving left on Nagle's screen. "Not bad, man," says Nagle, "not bad."

Soon after, Nagle was able, with practice, to draw a crude circle on the screen with his mind, and he progressed to playing Pong and learning to move the cursor to click commands that control his television, turning it on and off, changing the stations, and adjusting the volume. "It's like riding a bicycle," says Donoghue. "At first he's wobbly, he oversteers, and then he's suddenly riding." Nagle can talk and operate the computer at the same time, just as a healthy person might sing a song and walk. "This is important, because he doesn't need to actively think of moving his hands to the left or right," says Donoghue. "He just thinks about moving the cursor, and it moves."

To understand what Braingate means for Nagle, I visit Leigh Hochberg, the Harvard neurologist. Hochberg, who is a consultant at the Spaulding Rehabilitation Hospital in Boston, works with patients who have suffered strokes or severe spinal-cord injuries. He shows me the Assisted Technology Group's room at Spaulding, where quadriplegic and other severely disabled patients come to operate computers and other machines using devices hooked up to eyelids or lips or tongues, whatever they can still move. For those with no muscle movement, special cameras track pupil motion, which patients have learned to control in order to operate cursors. Others inhale and exhale through a straw to move a wheelchair.

Hochberg is the chief investigator for the Cyberkinetics FDA trial at Spaulding; this was the second site chosen for the trial, after Sargent Rehabilitation Center in Warwick, RI, the base for Nagle's trial. Hochberg and coinvestigator Joel Stein, Spaulding's medical director for the stroke program, have begun recruiting patients to fill the spaces allowed under the FDA license. Surgenor also wants to open another clinical-trial site, possibly in the Midwest. This will become even more important if the FDA approves human Phase II trials, which would involve up to several dozen patients.

"I think in the short term we're not looking for a cure for spinal-cord injury," says Stein, who nevertheless believes that in the long term Braingate will prove useful for patients with certain types of motor injuries. "We don't want to oversell this to our patients, but the potential in the future is great."

**Will these devices improve people's lives? Nagle himself says that Braingate, at least in its current form, is only marginally helpful.**

### The Color of Thought

At Brown University, I met computer expert Michael Black, an alumnus of the famed Xerox Palo Alto Research Center in California. Black is best known for trying to devise machines that can see, although he has also done research on brain-computer interfaces. Black was quickly sold on the possible benefits of Braingate and took on the task of creating improved algorithms for deciphering neuronal spikes. In theory, better deciphering would allow finer motor control. He showed me some charts with colored pixels that he developed to visualize what happens when a neuron fires. Each chart depicts a neuron's activity across a range of hand motions. The chart is blue where the neuron is inactive and shaded purple, orange, and then red where it becomes excited and spikes rapidly. (For example, a blue field with a bright red patch in the upper right corner means that this neuron becomes active when the monkey's hand moves up and to the right.) These grids tell Black the firing patterns of a neuron, which he can model to tell a computer that a given thought command is occurring and that it should take the appropriate action. The key to creating these models, he says, is the amazing tendency of brain neurons to fire in relatively consistent patterns—consistent enough that a computer can accurately interpret them.

In a building across Brown's campus, I talked to another member of Donoghue's team, Arto Nurmikko, a Finnish electrical engineer and physicist known for his discoveries in laser optics and semiconductors. He and Donoghue are working to simplify Braingate and replace the titanium pedestal and the bulky hardware of the prototype with a much smaller internal system that would connect the implant to a hair-thin fiber-optic cable that would run under the skin of the patient. The fiber-optic cable would feed signals from the brain to a processor the size of a cardiac pacemaker, which would be implanted in the chest.

The technology will take a while to develop. But Nurmikko says that in this next-generation system, communication between the brain and the machine would be two way, with sensory information from a robotic limb relayed back into the brain, just as in a healthy person. When a patient reaches for a glass of water, for example, such neural feedback would help brain and computer calculate the effort necessary to pick it up.

### Waiting for Help

Will these devices improve people's lives? Nagle himself says that Braingate, at least in its current form, is only marginally helpful to him. "This thing was done to see if I could move a cursor with thought," he says, "and I did that in about three minutes." But Nagle forcefully points out that he wasn't doing much of anything before. "I sat here seven days a week with nothing to do, so I said, 'Why not?'"

According to the FDA protocol, the study involving Nagle is to last a year. "I'll have to decide next June if I want to take this out. I'm not sure I will continue on. I may want to wait until they have one that is smaller and easier to use." I ask him if he thinks he'll walk again, and he says that's what he's *really* waiting for. ■

*David Ewing Duncan's next book,* The Geneticist Who Played Hoops with My DNA and Other Masterminds from the Frontiers of Biotech, *will be out in May.*

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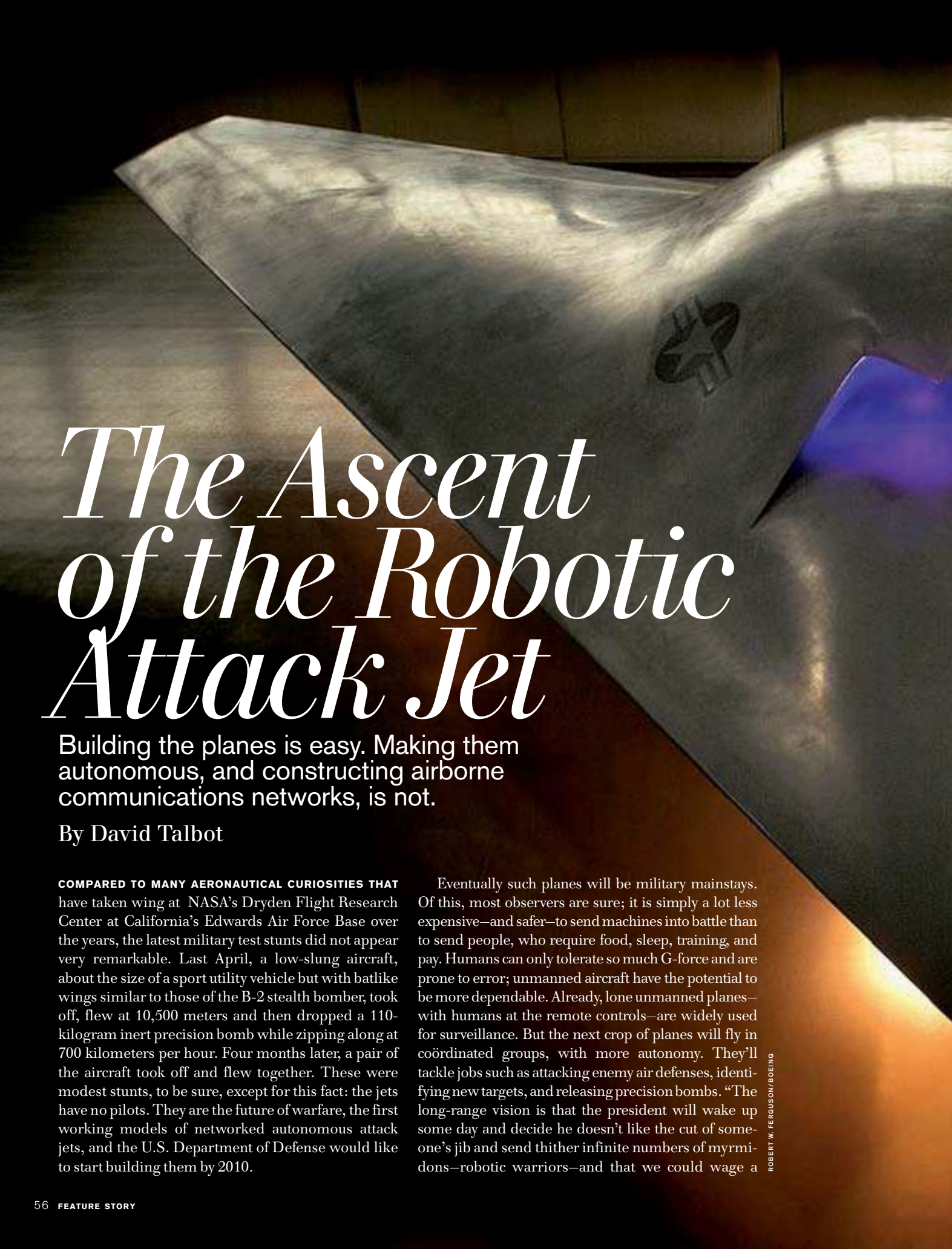


# The Ascent of the Robotic Attack Jet

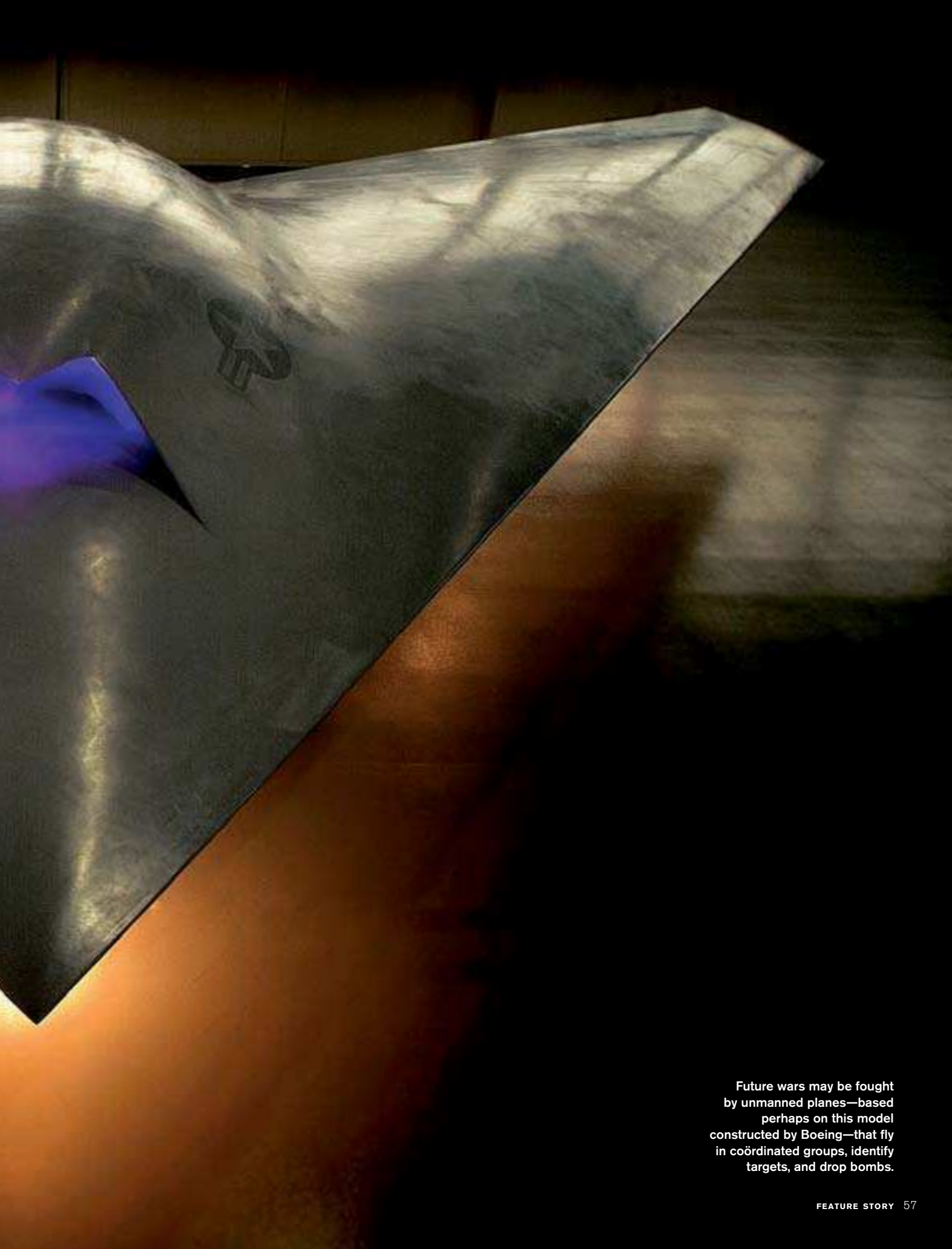
## Building the planes is easy. Making them autonomous, and constructing airborne communications networks, is not.

By David Talbot

**COMPARED TO MANY AERONAUTICAL CURIOSITIES THAT** have taken wing at NASA's Dryden Flight Research Center at California's Edwards Air Force Base over the years, the latest military test stunts did not appear very remarkable. Last April, a low-slung aircraft, about the size of a sport utility vehicle but with batlike wings similar to those of the B-2 stealth bomber, took off, flew at 10,500 meters and then dropped a 110-kilogram inert precision bomb while zipping along at 700 kilometers per hour. Four months later, a pair of the aircraft took off and flew together. These were modest stunts, to be sure, except for this fact: the jets have no pilots. They are the future of warfare, the first working models of networked autonomous attack jets, and the U.S. Department of Defense would like to start building them by 2010.

Eventually such planes will be military mainstays. Of this, most observers are sure; it is simply a lot less expensive—and safer—to send machines into battle than to send people, who require food, sleep, training, and pay. Humans can only tolerate so much G-force and are prone to error; unmanned aircraft have the potential to be more dependable. Already, lone unmanned planes—with humans at the remote controls—are widely used for surveillance. But the next crop of planes will fly in coördinated groups, with more autonomy. They'll tackle jobs such as attacking enemy air defenses, identifying new targets, and releasing precision bombs. "The long-range vision is that the president will wake up some day and decide he doesn't like the cut of someone's jib and send thither infinite numbers of myrmidons—robotic warriors—and that we could wage a

ROBERT W. FERGUSON/BOEING



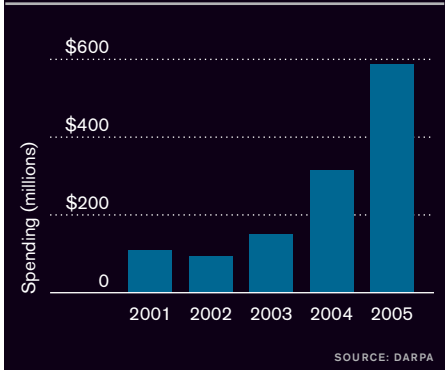
Future wars may be fought by unmanned planes—based perhaps on this model constructed by Boeing—that fly in coördinated groups, identify targets, and drop bombs.

war in which we wouldn't put at risk our precious skins" is how John Pike, director of GlobalSecurity.org, a leading defense policy website, puts it.

Realizing this vision will require the creation of new airborne communications networks and a host of control systems that will make these jets more autonomous (though always under the ultimate control of a person) than anything built to date. These are the goals of a $4-billion, five-year program at the Defense Advanced Research Projects Agency (DARPA), the Pentagon's advanced research arm. Though proposed Pentagon cuts are likely to push funding downward, the program is now DARPA's largest. Under the program, the agency is paying aerospace behemoths Boeing and Northrop Grumman to develop distinct jets with common control systems; DARPA recently signed on the Johns Hopkins University Applied Physics Laboratory to help with the myriad networking, control, and processing problems. Because, while DARPA is ordering up new flying machines, it is also requiring something far more important: the electronic brains to make them work. The jets "are technologically advanced aircraft, to be sure, but the soul...lies in the command and control, sensor, and weapons systems that enable their operation, individually and collectively," explains DARPA program director Michael Francis.

## The Pentagon Bets on Robotic Combat Aircraft

R&D funding has nearly quadrupled in two years, but faces proposed cuts in 2006.




The brain—which is housed on board and within ground-control stations—must do some difficult new things. It must not only keep the plane aloft and on course, but enable groups of planes to fly in coördinated fashion. It must rapidly keep up with changing communication links as the jets slice through the atmosphere at 700 kilometers per hour or faster. It must help make preliminary targeting decisions and drop bombs. While the planes must include the latest networking bells and whistles, they mustn't be too complex to use, so that a single controller—on the ground or in a manned jet flying with the unmanned ones—can effortlessly shepherd fleets of them.

Making each piece work—and adaptable to new missions, and applicable to different flying machines that may be built in the future—presents daunting software and control challenges. But if it works, it could transform how war is waged.

### Successful Predator

In recent years, unmanned planes have proven themselves in war. For example, the Predator, a medium-altitude surveillance plane made by General Atomics, debuted in Bosnia and then served in Afghanistan and Iraq. The Global Hawk, made by Northrop Grumman, has been flying high-altitude reconnaissance missions for years. Meanwhile, Northrop has built and flown another unmanned prototype, called Pegasus, and shown that it could land on an aircraft carrier. But the Pentagon's massive push for robotic attack planes began in earnest in 2003. That's when the Pentagon set up the Northrop–Boeing competition and established a seven-year timetable to develop versions suitable for the air force and navy.

Boeing's version is called X-45; a scaled-down prototype is what dropped the inert bomb last year, and a full-size model is under construction. Northrop's version is called X-47; it builds on the Pegasus, and the next generation model is still under development. The X-45 is geared more to high-speed air force attacks, and the X-47 to naval reconnaissance and carrier landings. In both cases, the largest prototypes* are supposed to take their first test flights within two years. (Amid the current budgetary uncertainty, DARPA declined to make its researchers available for comment. Comments from DARPA officials in this story come from agency transcripts of presentations the officials made last year.)

**WWW.TECHNOLOGYREVIEW.COM** For more views of the Boeing and Northrop Grumman projects, see our online slide show. Keyword DARPA.

It's not yet clear how many of which version the Pentagon might eventually want to buy. In that important way, this effort differs from the intense, winner-take-all competition to build the F-35 Joint Strike Fighter, widely seen as the last manned fighter jet. Boeing lost the F-35 competition to Lockheed Martin in 2001. "It caused [Boeing] to skip a whole generation of fighter aircraft, after being the foremost fighter aircraft supplier," says Paul Nisbet, an aerospace industry watcher at JSA Research in Newport, RI.

Boeing's initial pair of scaled-down X-45s have already proved themselves in several initial demonstrations. In 2003, Boeing passed one milestone, showing how the plane's ground controllers could coördinate flight plans with conventional air-traffic controllers and modify the X-45's flight plan as needed. Then, in 2004, Boeing's X-45s demonstrated a few more tricks—deploying inert bombs and, critically, demonstrating that its ground controllers could hand off the wireless yoke to another station nearly 1,400 kilometers away while the plane was in the air. Finally, Boeing showed that a single ground controller could control two X-45s.

And Boeing has another—perhaps more important—ace in the hole. The Pentagon already considers Boeing its "lead systems integrator" for a development project called Future Combat Systems. This mega-project is supposed to yield 18 kinds of sensor-riddled combat vehicles and the advanced communications technologies to link soldiers with vehicles, planes, robots, and each other.

This program is also likely to get scaled back as part of a new round of Pentagon cuts; the new emphasis will be on adding technology to existing vehicles. Still, "both of these programs are talking about putting robots on the battlefield," says Pike. "Boeing has looked at it and basically said, It's the future. They are the lead company for robots on the ground battlefield, and they've staked out a pretty tall position for

KENT RUMP

A Northrop Grumman illustration shows one war-fighting vision: unmanned jets that take off from aircraft carriers.

aerial robots." But Boeing and Northrop recognize that the current program isn't about who can build the best plane. "Before, we were looking at building the best platform," says William Body, a Boeing manager for business development at the company's R&D outpost, Phantom Works, based in Saint Louis, MO. "Now we are looking at creating the system-of-systems. We'll have unmanned planes, we'll have core technologies. But the endgame here is a network-centric endgame."

In a Boeing demonstration last year, a scaled-down prototype of its unmanned jet dropped a precision bomb at a military base in California.

### Nitty-Gritty Things

The first and most obvious challenge is how to enable increasingly autonomous operation. This may seem like a problem nearly solved. After all, for years even the most mundane commercial jets have included autopilot features that maintain trim and course during long flights and that can also perform essentially automated takeoffs and landings.

Importantly, though, ordinary planes still, of course, have pilots sitting in the cockpits. Pilots make countless decisions to handle little breakdowns on the plane—and decide whether or not it's appropriate to engage automated systems at all. "It's not so easy when you don't have a pilot in there to take care of mishaps, faults, failures, and all that jazz," says Eric Feron, an aeronautical engineer at MIT who is not connected to the current DARPA program. "It's unbelievable how much the human is able to act as the glue between the technological gaps. The human covers so many nitty-gritty things, from frequency switching to target acquisition and recognition."

Then there is the problem of constructing what amounts to an Internet in the atmosphere. On the ground, mobile communications networks are fast expanding, thanks to cellular and Wi-Fi networks. But when you get up to 10,500 meters at speeds of 700 kilometers per hour or faster, new challenges arise. To pick one technical example: today's airborne radio links incur one bit error in every 10,000 bits sent. That's far too unreliable for an airborne Internet. In fact, it's 100 times worse than what's needed for the ground-based Internet to provide even minimal service, says Dave Kenyon, an information architect at the air force's Electronic Systems Center in Bedford, MA. The center is developing satellite-based networks that will be used by all kinds of military planes, including future unmanned planes.

But even when satellites are used, the fact remains that jets cover great distances, and that communication links will thus regularly break. "From a networking perspective, the frequent making and breaking of links will require new or improved network routing protocols," Kenyon says.

In other words, the unmanned planes will require new ways for information to change communication pathways on the fly—literally. "We will not always have perfect communication and, in fact, will always have some form of latency," says Paul Waugh, a DARPA deputy director of the X-47 program. "Thus, the system, in all its parts, demands some level of autonomy, which means we will need smart platforms, smart sensors, and smart data processing." The plane needs to think for itself, at least during the gaps. "We recognize that we have entered perhaps the richest, deepest part of the information revolution that deals with mobile, wireless computing," Waugh says.

To further reduce strain on the communications networks, the planes must be designed to do as much work on board as possible. For example, after collecting images of targets, a plane must do much of the processing and filtering, sending only the most relevant images back to the human controllers. "The lines of code [for flying the plane] are minuscule compared to the lines of code required for mission planning, sensor management, and getting aircraft to fly together as a team," says Rick Ludwig, the business development manager for Northrop's program.

Eric Feron is developing a key system that is generic to all unmanned aircraft: the human–machine interface. In the future, unmanned jets might be controlled by a pilot in a single manned fighter jet. Feron is working on a natural language interface, so that the pilot can "talk back and forth with the [unmanned jet] as if it were just another person," Feron says.

But that's only part of the task; once the spoken commands are conveyed, those commands must be translated into a set of electronic and mechanical actions. Feron is also writing software that sorts and prioritizes commands and turns them into instructions that the machine can act on. Last June this command-and-control part of the system was successfully tested—using typed commands—on surrogate aircraft.

Above all, the software—which DARPA calls the "common operating system"—must be adaptable. The Northrop and Boeing versions are supposed to connect to one another and to other military systems—including those only yet envisioned. In various corners of academic, corporate, and military labs, autonomous helicopters, desk-sized robotic planes, and even insect-sized, flapping-wing aircraft are in various stages of development. If the networking and control systems are worked out, any future aircraft could make use of them. Once the airborne networks are as reliable as the land-based Internet, the myrmidons can take any form that pleases the Pentagon. ■

*David Talbot is* Technology Review*'s chief correspondent.*

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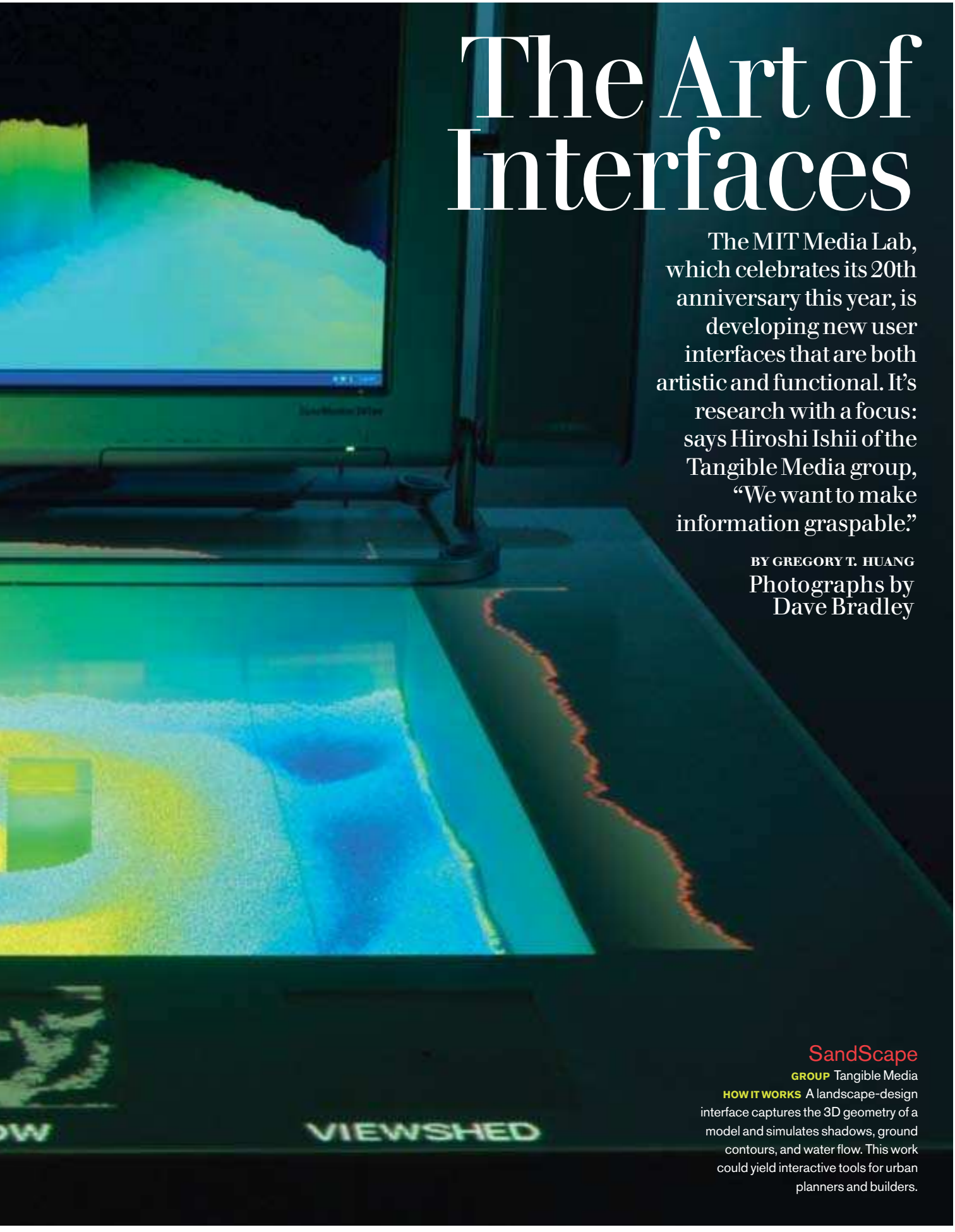
# Demo

# The Art of Interfaces

The MIT Media Lab, which celebrates its 20th anniversary this year, is developing new user interfaces that are both artistic and functional. It's research with a focus: says Hiroshi Ishii of the Tangible Media group, "We want to make information graspable."

BY GREGORY T. HUANG

Photographs by Dave Bradley




## SandScape

**GROUP** Tangible Media

**HOW IT WORKS** A landscape-design interface captures the 3D geometry of a model and simulates shadows, ground contours, and water flow. This work could yield interactive tools for urban planners and builders.

## Chromafant Blossom

**GROUP** Robotic Life

**HOW IT WORKS** Using infrared sensors, this flower detects a wave of a hand, sways, and changes color. Devices that sense and respond are crucial for next-generation surveillance and safety applications.

## Beatbugs

**GROUP** Hyperinstruments

**HOW IT WORKS** Tod Machover's digital musical instruments are networked together so users can trade sounds and play rhythms collaboratively. This research could lead to new games and toys that encourage kids to interact musically.

## Dragon Iris

**GROUP** Robotic Life

**HOW IT WORKS** This robotic flower in Cynthia Breazeal's lab senses heat and orients itself toward people. Making robots aesthetic and interactive paves the way for more engaging robotic toys and decorations.

## I/O Brush

**GROUP** Tangible Media

**HOW IT WORKS** A camera and tactile sensors in the brush let a user touch an apple, say, and then "paint" on the screen using that color and texture. This project could lead to new software applications and tools for artists and graphic designers.

# Kalashnikov's Gun

## The AK-47 and Russian engineering

One of Russia's newest museums is devoted to what may be the world's deadliest work of art, the AK-47 assault rifle. In the western Urals, a redoubt of weapons manufacture since Tsarist days, the museum might be dismissed as a shrine of nostalgia for the Soviet arsenal. Yet the AK-47 remains a unique advertisement for a distinctly Russian approach to technology, one with lessons beyond the world of weapons enthusiasts.

The Kalashnikov is the most successful firearm in history. William Hartung and Rachel Stohr report in *Foreign Policy* that between 70 and 100 million of the weapons are in circulation, compared with just seven million U.S. M-16s. In Afghanistan, the AK-47 costs as little as $10.

The AK-47 has become a global brand, the preferred weapon of revolutionaries and insurgents for decades, but nevertheless uniting the bitter adversaries of the Cold War. Lt. Gen. Mikhail Kalashnikov, 85, is a lifetime member of the National Rifle Association, even though the Central Museum of the Armed Forces in Moscow features an AK-47 that was used by a North Vietnamese soldier to kill 78 U.S. troops. Indeed, the same museum collection shows Egyptian and Chinese knockoffs used by anti-Soviet Afghan fighters, and countless similar ones are in the hands of al-Qaeda.

The AK-47 illustrates the power of incremental adaptation. As a tank sergeant in World War II, Mikhail Kalashnikov saw that most Soviet troops had only carbines against the superior range of the German *Sturmgewehr*. While recovering from battlefield wounds, he began to create a design for a new weapon, one that could be assembled with relatively loose tolerances by relatively inexperienced workers, avoiding the supply bottlenecks that often resulted from the German cult of fine craftsmanship. A tractor plant originally produced the gun. Not only was the AK-47 simple to manufacture, but it could withstand rough handling in harsh terrain and climates.

Russian ingenuity flourishes in isolation and adversity. When I visited Moscow in 1988, I saw the result of a minor car crash near the giant Rossiya Hotel. A fender bender dented the heavy Soviet sheet metal, when lighter Western metal parts would have creased or plastic parts shattered. There were surely brigades of body-and-fender men ready to hammer them back into shape rather than bolt in new replacements. The scarcity of consumer goods, in fact, helped promote of ubiquitous fix-it (*remont*) shops for small appliances wherever I walked in Moscow; try to find their counterpart in the capitals of the throwaway West.

Thus, the worldwide success of the AK-47 design was not a fluke. Even the United States has bought Kalashnikov-style arms from factories in former satellite countries in order to equip its allies in Afghanistan and Iraq. The designer and Russian authorities have even claimed violation of intellectual property laws for these knockoffs. Whatever the ultimate settlement, the decline of the market for Russian successors to the AK-47 reveals an unintended consequence of its rugged, reliable simplicity. It is all too easy for non-Russians, including anti-Russian terrorists, to reuse, repair, and manufacture it.

The Russian style does have other, more benign outcomes. A U.S. aerospace company has imported NK-33 liquid fuel rockets, first developed in the 1960s, for their exceptional reliability. Russia remains a major exporter of night-vision goggles, with 15,000 workers in the consumer night-vision industry in 1999. And Tetris, which helped launch Nintendo's Game Boy in the late 1980s, achieved its addictive fame through ingenious use of the limited processing power and memory of the day; it was the masterpiece of Alexei Pajitnov, a mathematician in the Soviet Academy of Sciences.

Pajitnov, who has lived in the United States for more than 13 years, continues to create puzzle games with a global following. He has described Tetris as "a kind of game which helps you order the world. You fight against chaos." Which is itself a Russian setiment. Because Russia has often stood at the edge of chaos, its best technology is art of a special kind. ■

NRA member Lt. Gen. Mikhail Kalashnikov, at the 50th anniversary celebration for the AK-47 in 1997.

MISHA JAPARIDZE/AP PHOTO

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# Chronic Pain

## Why we still need a strong, healthy FDA.

**BY STEPHAN HERRERA**

Over the course of just a few months last year, Americans learned that the U.S. Food and Drug Administration had underestimated the severity of manufacturing problems at Chiron, one of the nation's leading flu vaccine suppliers; had misunderstood the heightened risk of suicide among children taking certain antidepressants; and had failed to publicize the correlation between deadly heart problems and the blockbuster medicines Vioxx, Celebrex, and Bextra.

President Theodore Roosevelt, who established the agency that would later become the FDA, knew that managing the expectations of a population that both loved and distrusted pharmaceuticals (and the companies that make them) represented a daunting challenge. But he reckoned that if America's medicines regulator succeeded more often than it failed, the public good would be served. The FDA *has* succeeded more often than it has failed, and the American public—and the drug industry—have benefited hugely. But the agency's failures have a way of overshadowing its triumphs.

During the Clinton administration, critics carped that the agency and its overzealous MDs and PhDs were overstepping their mandate, erring on the side of caution to the detriment of patients. Among other things, politicians and drug industry executives argued that the FDA was taking too long to review new drug applications. These same critics said long review times were bad for business and patients alike.

### Bitter Pills

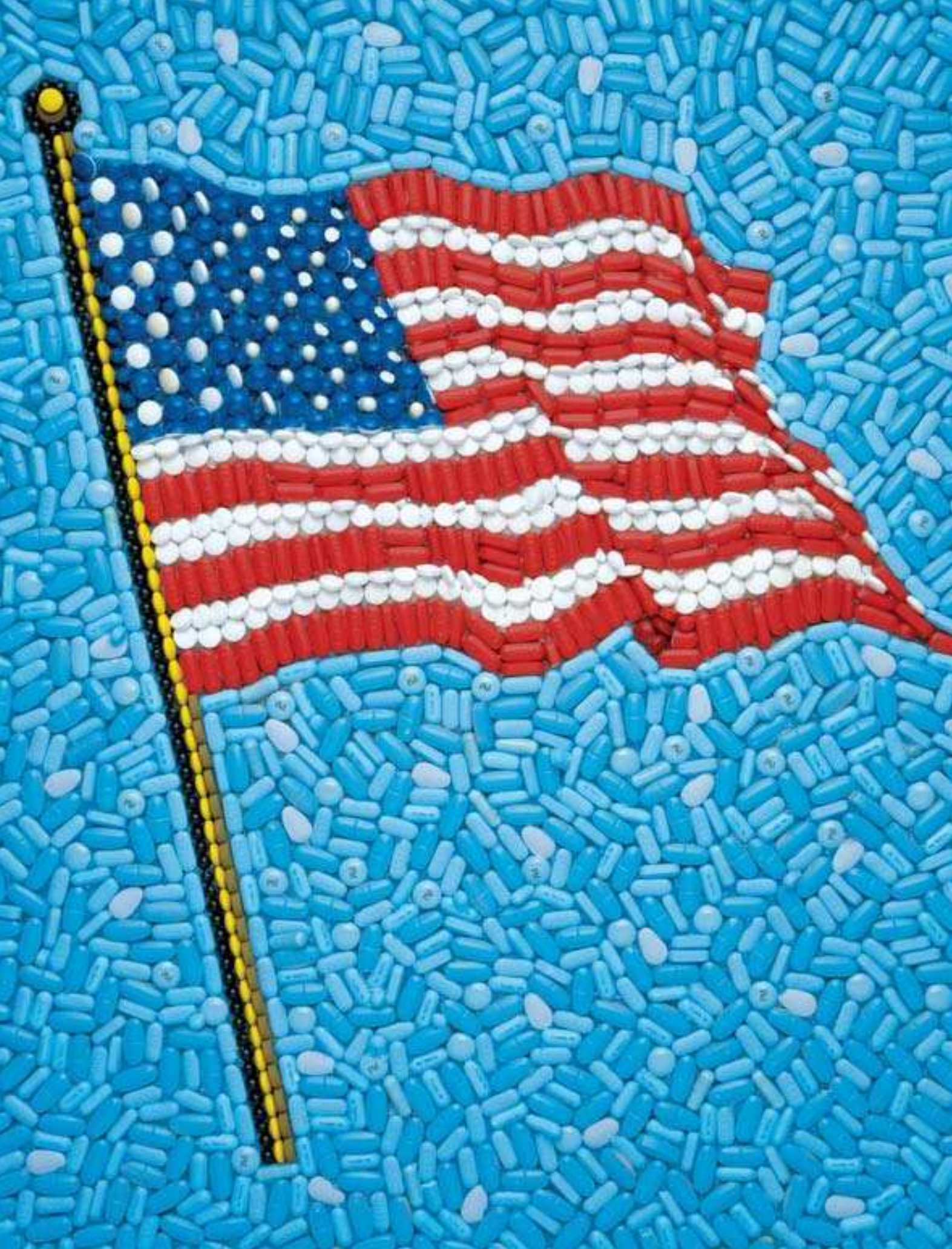
**Under Review: Protecting America's Health: The FDA, Business, and One Hundred Years of Regulation**
By Philip J. Hilts
Alfred A. Knopf, New York, 2003, $19.95

"Reforming" the FDA became a top policy objective during the "Republican revolution" led by then Speaker of the House Newt Gingrich during the mid-1990s. Then, in the early days of the Bush administration, the FDA went under the management consultant's knife and emerged talking a new kind of language. Achieving "excellence in management practices," "modernizing IT," and striving for "efficient risk management" became the new imperatives at the FDA. Management would be "de-layered"—all to "reduce average time to marketing approval" for new medicines and medical devices.

This new mantra at the FDA, however, seems to have distracted the agency from that other "core competency" product safety, resulting in a string of dangerous miscalculations.

A different set of critics this time—the media, government-watchdog groups, the medical establishment, even FDA scientists and advisors—are now saying that the agency has tilted too far in the other direction, overemphasizing product-review speed and industry accommodation and sacrificing patient safety issues

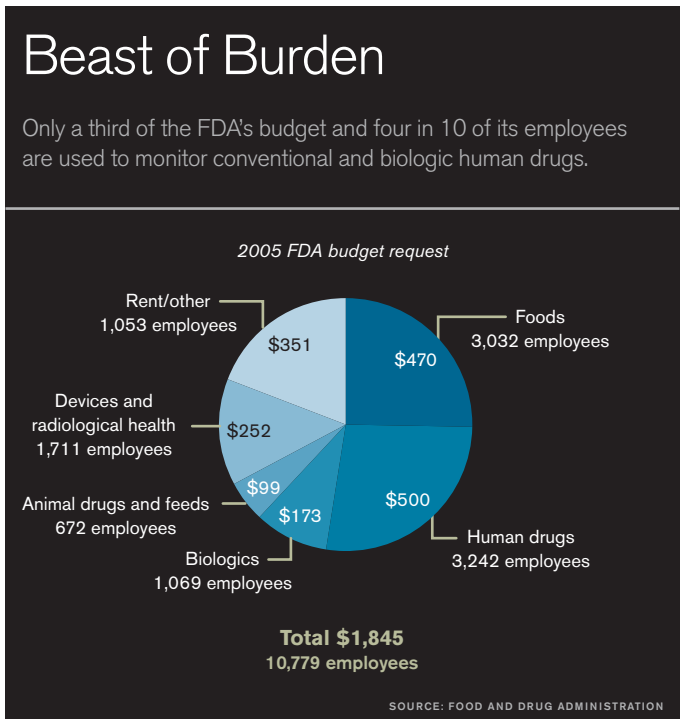
JASON MECIER



that come up *after* drugs have been approved. One of the FDA's own scientists, a mid-level staffer named David Graham, testified before Congress in November that the Vioxx fiasco was preventable. He revealed that his employer took the assurances of Merck, the drug's manufacturer, over the warnings of its own senior scientists and advisors. Graham told Congress that as many as 139,000 patients suffered heart problems—55,000 of whom may have died—as a result of taking Vioxx. And he said both Merck and the FDA are to blame. The only way to prevent future fiascoes, Graham testified, is to create an independent drug-safety review board whose sole responsibility would be to monitor products *after* they reach the market. He noted that the system at the FDA for catching problems with marketed drugs is largely voluntary and relies upon doctor and drug company reports that are often slow in coming or incomplete.

Within days of Graham's bombshell, an editorial on the website of the *Journal of the American Medical Association* reiterated that the FDA is badly in need of an "adverse drug reaction" reporting system whose success does not depend on drug companies to draw attention to problems associated with their big moneymakers. In most cases, after all, there is a disincentive to be honest and swift about product problems. Investors don't like this kind of product surprise. Last September, the day after Merck announced it was pulling Vioxx, Wall Street erased $27 billion from the firm's market value; in December, the day Pfizer announced that Celebrex, too, causes heart problems, investors took back $25 billion. Liability specialists reckon Merck will lose another $18 billion to $20 billion settling personal injury suits.

These are dark days indeed for the FDA. But they will pass, and the FDA will press on in its thankless task of keeping America safe from bad drugs, devices, and food. At least this is the lesson that history tells. To hear Philip J. Hilts tell it, the FDA has endured worse. Hilts explains in his well-timed book *Protecting America's Health: The FDA, Business, and One Hundred Years of Regulation* that controversy and criticism have dogged the FDA ever since it was created to take on tainted food and patent medicine peddlers. It survives because it must.




## Say AAAH

To get a sense of just how important the FDA is to America's economy, consider that the agency is responsible for the regulation and oversight of nearly a fifth of all consumer expenditures in the country. The agency is not merely responsible for the health and well-being of 300 million Americans; it is also essentially responsible for the good behavior of one of the most powerful industries ever created—the American drug industry. There are bound to be misadventures. It's a wonder that there aren't more. In 2003 alone, close to three and a half billion prescriptions were dispensed in the United States.

Contrary to what some are now suggesting, however, America does not need a new medicines regulator or a new bureaucracy to oversee the FDA. What America needs is President Bush and the Republican-led Congress to give the FDA the tools, authority, and freedom it needs to succeed. In short, what America needs is a better understanding of the FDA.The agency is overworked, underfunded, poorly managed, and shamefully politicized. It has just 10,700 employees to evaluate and oversee the safety, effectiveness, and promotion of hundreds of thousands of medicines, medical and radiological devices, dietary supplements, food products, and cosmetics. There are around 100,000 drug companies to monitor and more than nine million channels through which food, medical, and cosmetic products are imported. With an annual budget of $1.5 billion, the FDA is responsible for overseeing nearly $1.5 trillion worth of products. And it has been forced to do so with only a whisper of leadership. Over the past four years, the FDA has had a bona fide commissioner for all of 16 months. Over the past 40 years, the average tenure of an FDA commissioner has been four years and five months.

Curiously, consumers on the whole seem satisfied. But as Hilts writes in his insightful and edgy history, nobody stops to think much about the FDA until he or she suffers the real or perceived side effects of its real or perceived failures. Yet other than the military, has any government institution done more to protect the nation against bodily harm? Doubtful, but because the FDA has always been the subject of ideological attacks, it is judged more for its shortcomings than for its quiet successes.

"In some circles, the fashion is still to criticize the 'government' and the 'government regulators' as if they were occupying armies rather than citizen-soldiers," writes Hilts. "The FDA has nevertheless proved itself an essential part of modern society. Its history demonstrates that regulatory agencies can not only establish effective protections but make high scientific standards the starting point for industry."

Hilts tells us that when enemies of the FDA are not actively trying to legislate the agency out of existence, they are attempting to marginalize it by cutting its funding and curbing its authority. No other health-related government agency is forced to do so much with so little money or power. Today, for example, the National Institutes of Health, the government's medical-research arm that

regulates no industry and is responsible for nobody's health or well-being, operates on a budget of close to $28 billion a year, while the FDA must make do with about one-twentieth of that amount of money. The FDA's budget is about one-fifth that of the Environmental Protection Agency, which is only responsible for some aspects of public health.

Yet much is demanded of the agency. The politicians who are not trying to upend the FDA want it to help curb health-care costs and foster medical innovation. Industry wants the agency to speed up the approval process, which now takes, on average, less than 12 months, and to reform protocol to take into account clinical-trial innovations. Watchdogs (including the federal government's own Government Accountability Office) want the FDA to act more proactively and decisively on such matters as food safety, alternative medicine, and industry shenanigans connected to political contributions and the $2.7 billion direct-to-consumer advertising juggernaut. Health insurers want the FDA to create a regulatory pathway for generic medicines, against the will of proprietary drug companies.

The American Medical Association and the Association of American Medical Colleges are demanding that the FDA figure out how to create a public registry for clinical-trial data without invading the privacy of patients or revealing confidential product information. And such distinguished observers as *Science* editor in chief Donald Kennedy, who served as commissioner of the FDA from 1977 to 1979, want the FDA to create and enforce a system that can "detect things that go wrong with an already-marketed drug."

**_Science_ editor in chief Donald Kennedy writes, "Instead of complaining about the FDA, Congress should fund it to support an effective Office of Drug Safety."**

Writing in the December 3, 2004, edition of *Science*, Kennedy asserts that in light of the Vioxx scandal, the most useful and important new tool Congress could give the FDA would be a centralized system for tracking how much of a given drug is being used per patient and over how much time, so that a denominator could be established and an adverse reaction rate calculated. He and others have noted that Kaiser Permanente has just such a system in place, which allowed the health insurer to spot the Vioxx problem early through the use of adverse-reaction epidemiology studies. "Instead of complaining about the FDA," Kennedy writes, "Congress should fund it to support an effective Office of Drug Safety, with the authority needed to encourage physician reporting and a way to audit prescriptions."

Unlike most FDA finger-waggers, Kennedy acknowledges that what needs to be done and what can be done are quite different. Kaiser, he says, can create a centralized database of patient records, for example, because customers willingly entrust their privacy to Kaiser. The United Kingdom is able to create a national health-records registry not necessarily because the population trusts the government—rather the contrary—but because it's the law, and the law was passed in Parliament on the promise that it will improve for all what had become an abysmal health-care system that served nobody particularly well.

"If we were to try and give the FDA something like these two systems," Kennedy says, "you'd hear cries of privacy invasion." But this is a chasm we must eventually cross. Privacy advocates and antigovernment critics will object, but eventually America will find a way to link the FDA to patient records. National health-record databases are the future. Last year, the United Kingdom began to build a lifelong health-records database for the 50 million patients in its public-health system, which is linked to 30,000 general practitioners and 270 hospitals and clinics in the U.K. Sweden, Denmark, and Japan are talking about the feasibility of creating similar databases in their own countries. Growing populations with new and more complicated health needs will force the matter. No government agency is in a better position than the FDA to manage such a database.

### Greed and Goodness

A registry would, of course, be a dramatic expansion of the FDA's jurisdiction. Privacy advocates won't be the only ones concerned about this. Bioethicists and academics argue that the FDA has its share of problems without adding on the job of managing a clinical-trials database and a citizens' health registry. Conservatives and industry leaders will not be keen on the idea either, not least because it would be hugely expensive and put valuable information into the hands of government. As Hilts writes, the agency still finds itself trapped between competing constituencies: "Should the department err on the side of safety and the consumers? Or should it err on the side of business freedom until practices [are] proved to be dangerous?" Hilts concedes in his epilogue, "Greed and Goodness," that despite pressure to do otherwise, the FDA should by now understand the risks that are inherent in the latter choice.

Hilts cites a series of experiments first hatched by J. Scott Armstrong, a management professor at the Wharton School at the University of Pennsylvania, that proved that if asked to play the role of a drug company executive, students put the interests of shareholders before the interests of patients taking the company's medicines. "The experiment was repeated 91 times, in 10 countries, with 2,000 subjects and 23 different experimenters," Hilts writes. "If the membership of the company's board was not artificially altered to include outsiders and specific details about harm were not given, in North America and Europe, 76 percent of the board members took the most irresponsible course. None chose the most responsible course."

Of course, there are conservative partisans in America who have long felt that it would be best to narrow rather than expand the FDA's mandate. In 1996, in fact, House Republicans introduced legislation that would have obliterated that mandate. Fortunately, the bill got nowhere. Hilts says that history proves that the Right has never liked the FDA. But he makes note that the Right's hatred and angst reached its apogee during the days of the Republican revolution. In the House of Representatives in 1996, "the Republican leadership was expected to drive the FDA

'reform' through in short order," Hilts writes. "It was, as the conservative Republicans saw it, a battle of monetary and political force in the service of moral certainty."

In a column in *Reason*, science correspondent Ronald Bailey sums up the Right's mantra: "Being too cautious can kill you. And the FDA is the avatar of bureaucratic caution." This fixation seems to endure even when tragic events like those involving Vioxx suggest that the FDA is often not cautious enough.

Bailey uses as an example the gene therapy tragedy that took but one life, that of Jesse Gelsinger in September 1999. The FDA shut down similar trials of gene therapy within weeks of the news and launched investigations to find out what had happened. Bailey charges that the FDA overreacted: "The FDA began hastily scrutinizing all gene-therapy trials with an eye to finding not just egregious violations, but even technical paperwork missteps. Spooked bureaucrats who want to stop something that they fear might get them in trouble tend to bury those they regulate in mounds of paper and interrogatories."

**The FDA is ill-equipped to handle the complexities of emerging technologies that don't easily fit into the standard FDA protocol.**

Bailey rightly points out that whether the FDA misunderstands the risks and rewards of new medicines like gene therapy, or simply overreacted to one clinical trial's tragic result, it is ill-equipped to handle the complexities of emerging technologies that don't easily fit into standard FDA protocol. Medical therapies will only become more scientifically complex, so the FDA had better hire the staff and purchase the tools necessary to approve the new medicines and then monitor them carefully once they are on the market.

### How to Heal the FDA

Staying one step ahead of new technologies, let alone balancing their risks and rewards, is no small challenge—especially for a large bureaucracy without a proper leader. Lester Crawford, the acting boss, is by all accounts a decent man, but he's a caretaker. The FDA needs a leader strong enough to obtain the money and autonomy the FDA needs to do its job—a leader wise enough to reconcile the competing needs of the public and the hugely powerful industries that it regulates. The agency needs an inspiring manager with a public face that the American people recognize and trust, and a stalwart that industry respects—perhaps even fears just a bit. Now that Michael Leavitt, the former chief of the Environmental Protection Agency and an ideological soul mate of President Bush, has been hired to run the Department of Health and Human Services—whose jurisdiction includes the FDA—the White House and Congress must turn their attention to filling the void at the top of the FDA.

As Kennedy and others have noted over the past few years, the White House and the Republicans on Capitol Hill have wanted to put a politically reliable figure in charge of the FDA. The FDA would benefit more if it got somebody like Walter G. Campbell, who served two tours as chief between 1921 and 1944, for a total of 20 years. Interestingly, Campbell was neither an MD nor a PhD, but a Kentucky lawyer who was handpicked, Hilts tells us, by Harvey Wiley, the agency's first head and a man who, like Theodore Roosevelt, began his professional life as a Republican only to leave to join the Progressive movement. In addition to giving the FDA stability—he remains the longest-serving chief—Campbell gave the agency armor-coated legitimacy.

The next FDA boss must sometimes turn a deaf ear to politics and find a way to prove to doubters that the agency will never put the business interests of the drug industry ahead of the safety of the public. The next FDA commissioner must continue the "delayering" of the chain of command to improve communication between the labs and field staff, working to avoid future incidents where serious safety concerns get shouted down or overlooked. Most importantly, the new commissioner must do what is necessary to force Congress to give the agency the budget and authority that it needs to do its job properly. Congress should not be allowed to dither any further. The FDA was created in the first place precisely because Congress was viewed as an unreliable guardian of public health.

As the agency's first boss, Wiley, a food chemist, persuaded Roosevelt that Congress could not and should not be trusted to police the safety of food and drug products. Hilts writes that "what bothered Wiley, who loved both research and commerce, and participated in both throughout his life, was that in research there was a strong sanction against deceit, while in commerce deceit seemed to be an accepted tactic to achieve profits. There was some disjoint there." Wiley and Hilts demonize industry a bit much, but not entirely without cause.

The drug industry has competing interests; the FDA should not be put into a similar bind. As Hilts puts it, "The logic of 'profit alone' that dominated the companies in the nineteenth century still dominates them today. This is one reason the FDA's job is difficult, and necessary." The Vioxx fiasco could have been avoided. But it is also important to remember that Americans should not expect the FDA to squeeze out every last ounce of risk from food and drugs. Neither should politicians, drug industry critics, and reporters. New medical products bring new risks—that is their price. But with a few notorious exceptions, the FDA does everything in its power, given its overextended resources, to keep medicines that are unnecessarily risky off the market—and help the public understand the risks of those that are allowed past its gates.

Because of last year's scandals, those who denounce the FDA have fresh cause. But there will always be debates about whether the agency's quiet successes outweigh its misadventures. Yet 100 years after its establishment, this much is not in dispute: the FDA succeeds in its mission more often than not, despite needlessly long odds. It could do even better if it had the money, management, staff, and technology to do its job properly. ■

*Stephan Herrera writes about the business, science, and politics of medicine and health care. He is a contributing editor at* Nature Biotechnology *and a frequent contributor to the* Economist *and* Technology Review.

# Hack License

## Recent books struggle to define hacking and its economic and social legitimacy.

**BY SIMSON GARFINKEL**

As cultural critic and New School University professor McKenzie Wark sees things, today's battles over copyrights, trademarks, and patents are simply the next phase in the age-old battle between the productive classes and the ruling classes that strive to turn those producers into subjects. But whereas Marx and Engels saw the battle of capitalist society as being between two social classes—the proletariat and the bourgeoisie—Wark sees one between two newly emergent classes: the hackers and a new group that Wark has added to the lexicon of the academy: the "vectoralist class."

Wark's opus *A Hacker Manifesto* brings together England's Enclosure Movement, *Das Kapital*, and the corporate ownership of information—a process that Duke University law professor James Boyle called "the Second Enclosure Movement"—to create a unified theory of domination, struggle, and freedom. Hacking is not a product of the computer age, writes Wark, but an ancient rite in which abstractions are created and information is transformed. The very creation of private property was a hack, he argues—a legal hack—and like many other hacks, once this abstraction was created, it was taken over by the ruling class and used as a tool of subjugation.

So who are these vectoralists? They are the people who control the vectors by which information flows throughout our society. Information wants to be free, Wark writes, quoting (without attribution) one of the best-known hacker aphorisms. But by blocking the free vectors and charging for use of the others, vectoralists extract value from practically every human endeavor.

There is no denying that vectoralist organizations exist: by charging for the distribution of newspapers or Web pages, such organizations collect money whenever we inform ourselves. By charging for the distribution of music, they collect money off the expression of human culture.

Yes, today many Web pages and songs can be accessed over the Internet for free. But others cannot be. The essence of the successful vectoralist, writes Wark, is in this person's ability to rework laws and technology so that some vectors can flourish while other vectors—the free ones—are systematically eliminated.

But does Wark have it right? By calling his little red book *A Hacker Manifesto*, Wark hopes to remind us of Marx and Mao. Does this concept of "vector" have what it takes to start a social movement? Are we on the cusp of a Hacker Rebellion?

The Communists of the 1840s had more or less settled on the ground rules of their ideology—the communal ownership of property and social payments based on need—by the time Marx and Engels wrote their infamous tract. By contrast, many individuals who identify themselves as hackers today are sure to find Wark's description circumscribed and incomplete.

When I was an undergraduate at MIT in the 1980s, hackers were first and foremost people who perpetrated stunts. It was a group of hackers that managed to bury a self-inflating weather balloon near the 50-yard line at the 1982 Harvard–Yale game; two years later, Caltech hackers took over the electronic scoreboard at the Rose Bowl and displayed their own messages. (Another group had hacked the Rose Bowl 21 years before, rewriting the instructions left on 2,232 stadium seats so that Washington fans raising flip-cards for their half-time show unknowingly spelled out "Caltech.")

Hackers were also spelunkers of MIT's tunnels, basements, and heating and ventilation systems. These hackers could pick locks, scale walls, and practically climb up moonbeams to reach the roofs of the Institute's tallest buildings.

By the late 1980s, the media had seized on the word hacker—not to describe a prankster, but as a person who breaks into computers and takes joyrides on electronics networks. These hackers cracked computer systems, changed school grades, and transferred millions of dollars out of bank accounts before getting caught by the feds and sent to the pen.

Finally, there were the kind of hackers MIT professor Joseph Weizenbaum had previously called "compulsive programmers." These gods of software saw the H-word as their badge of honor. Incensed by the hacker stereotype portrayed in the media, these geeky mathlings and compiler-types fought back against this pejorative use of their word—going so far as to write in *The New Hacker's Dictionary* that the use of "hacker" to describe "malicious meddler" had been "deprecated" (hacker lingo meaning "made obsolete"). I remember interviewing one of these computer scientists in 1989 for the *Christian Science Monitor*: the researcher threatened to terminate the interview if I used the word "hacker" to describe someone who engaged in criminal activity.

Although the researcher and others like him were largely successful in reclaiming their beloved bit of jargon, they were never able to fully disassociate the word from its negative connotations. Today, the word "hacker" is widely accepted to have two meanings. One reason, of course, is that malicious meddlers continue to call themselves hackers.

Both *Hacking Exposed*, a mammoth three-author, 750-page book about to be published in its fifth edition, and *Hacking: The Art of Exploitation* seem to suggest that use of the word to describe someone with criminal intent is alive and well. There are very much two kinds of hackers: "white-hat hackers," who follow the programmer ethic and help people to secure their computers, and "black-hat hackers," who actually do the dirty business. The fact that it is the black hats who create the market demand for the white hats is something that most white hats fail to mention. Also overlooked is the fact that many who wear white hats today once wore black hats in their distant or not-so-distant past.

The idealized hackers for whom Wark has written his manifesto also routinely engage in criminal activity—by violating the vectorial establishment's laws of intellectual property. Vectorialists are not the only victims of these crimes. And Wark's hackers are the kind of people who would use peer-to-peer networks to let a million of their closest friends download Hollywood's latest movies before they are released in theaters—a prime example of hacker power to defeat the evils of vectorial oppression. On the

other hand, hackers also rent time on other networks in order to send out billions of spam messages hawking the latest in penis enlargement. When it comes to the hacker pastime of criminal computer trespass, Wark is silent.

### Freedom versus Free Beer

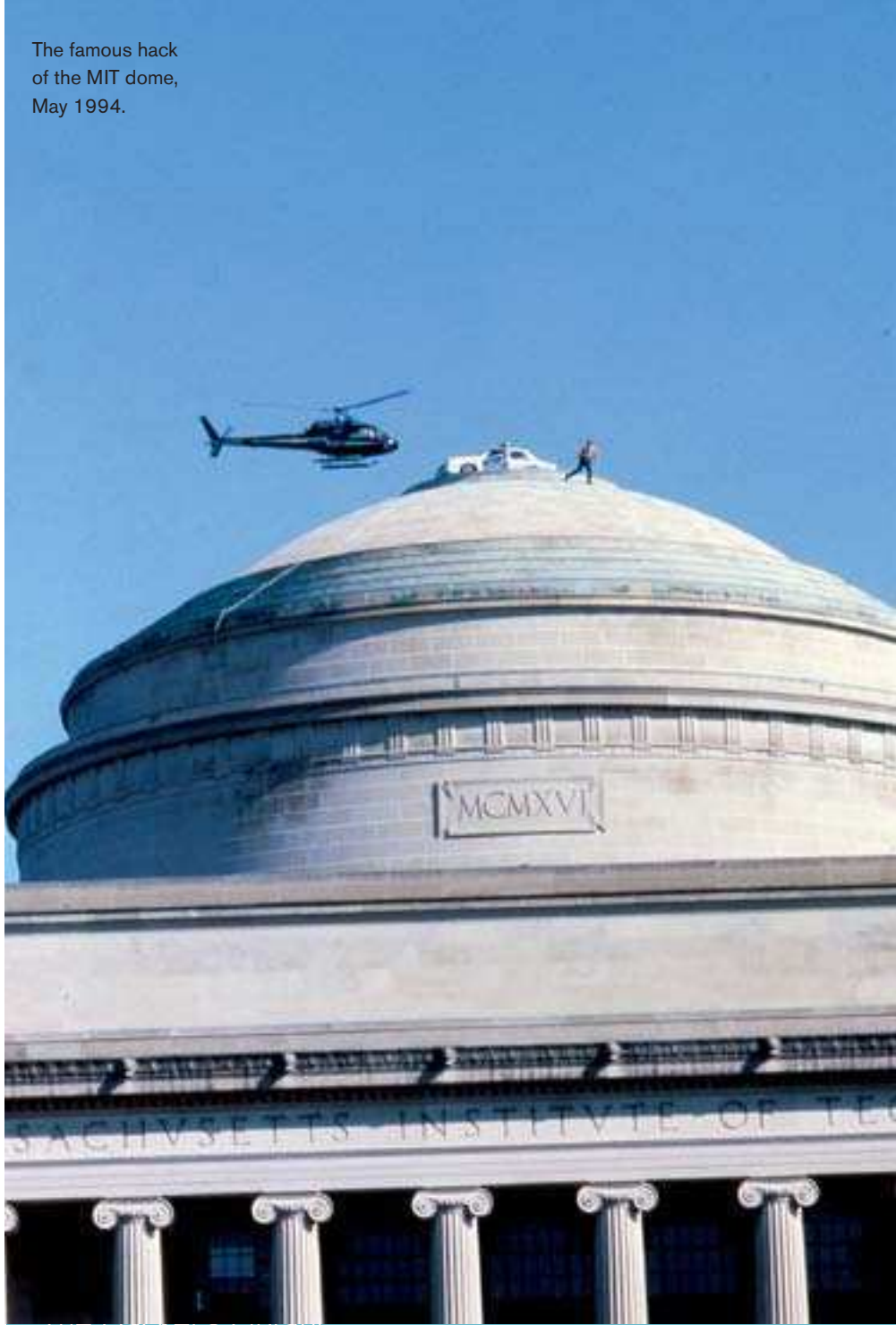
Absent as well is any reference to hardware hacking—or, indeed, any reference to hardware at all. To Wark, hacking is about bits, not atoms. The power of Big Vector is its ability to control information networks like the telegraph and the Internet, not transportation networks like FedEx. The intellectual property that Wark is concerned about is the property of abstraction: movies, programs, drugs. It's information that "wants to be free." Wark comes down pretty hard on the patenting of genetic information, but presumably the patents that apply to the design of piston engines or wind turbines are another matter entirely.

Hacker philosophers such as Richard Stallman and Lawrence Lessig frequently play up the fact that information can be given away without being relinquished. It is this fundamental fact that makes information different from other goods, they argue. It is why the old rules of property should not apply in the digital domain.

Stallman wrote in 1985, "the golden rule requires that if I like a program I must share it with other people who like it." Stallman continues, "Software sellers want to divide the users and conquer them, making each user agree not to share with others. I refuse to break solidarity with other users in this way. I cannot in good conscience sign a nondisclosure agreement or a software license agreement."

Stallman, more than anyone else, is rightfully credited with kicking off what we now know as the "open source movement"—which he calls "Free Software." That's "free" as in "freedom," not as in "free beer," Stallman is quick to point out. The culture of sharing software was in danger of dying out in the early 1980s when Stallman started the GNU Project and wrote "The GNU Manifesto."

GNU stands for GNU's Not Unix—an all too clever recursive hacker acronym. The original goal of the project was to create a free version of the Unix operating system. But Stallman worked hard to extend




The famous hack of the MIT dome, May 1994.

ERI IZAWA

## The Hacker's Library

**Under Review:**

**A Hacker Manifesto**
By McKenzie Wark
Harvard University Press, 2004, $21.95

**Hacking: The Art of Exploitation**
By John Erickson
No Starch Press, 2003, $39.95

**The Future of Ideas: The Fate of the Commons in a Connected World**
By Lawrence Lessig
Vintage, 2002, $15.00

**The GNU Manifesto**
By Richard M. Stallman
www.gnu.org/gnu/manifesto.html, 1985

**Hacking the Xbox: An Introduction to Reverse Engineering**
By Andrew Huang
No Starch Press, 2003, $24.99

**Hardware Hacking: Have Fun While Voiding Your Warranty**
By Joe Grand
Syngress, 2004, $39.95

the consciousness of programmers beyond mere lines of code and into the world of politics—specifically the politics of intellectual property. He staged a hacker protest at the headquarters of Lotus when that company tried to enforce copyright restrictions on user interfaces. He wrote and spoke, rallying against copyright restrictions and software patents.

Like "the Party" in *1984* and real-live Communists in China, Stallman promotes his ideology in part by rewriting everyday speech. He went so far as to publish an official list of "Confusing or Loaded Words and Phrases that are Worth Avoiding"—words like "commercial," "consumer," "content," "creator," "open," and "intellectual property." For example, he writes, instead of using the phrase "copyright protection," one should instead use "copyright restrictions," as in the sentence: "Congress recently extended the term of copyright restrictions by 20 years."

These tactics turned off supporters and were put to good use as counterpropaganda by his detractors—such as a software executive who once accused Stallman of being a Communist because of his collectivist software ideology. The emergence of the term "open source" amounted to a slap in Stallman's face: after all, it was a direct attempt to separate the mechanism of Free Software from Stallman's barefoot politics of free love, his vehement attacks on the beliefs and conduct of the Republican party, and his vigorous defense of personal freedom.

**"On the one hand information wants to be expensive, because it's so valuable. On the other hand, information wants to be free."**

Using Wark's framework, this all makes a kind of sense. Stallman is not opposed to big business and capitalism: he is opposed to big vector and the vectoralist agenda of creating a body of intellectual property law that eliminates the possibility of alternatives. Anyone committed to freedom must be opposed to the vectoralist class, because it profits through control.

From this Wark-Stallman view that intellectual property is really just a self-enriching tool evolves the conclusion that the world of computers would be better off without the majority of patents, copyrights, trademarks, and other legal means for restricting intellectual property.

Lessig, meanwhile, takes these mechanisms of restriction in a different direction. In *The Future of Ideas* he argues that a combination of legal and technical restrictions are fencing off our cultural heritage. In the not-so-distant future, perhaps, the very phrase "free expression" will become an oxymoron, as any self-respecting expression will necessarily have to pay licensing fees for numerous ideas, phrases, images, and even thoughts from well-funded copyright holders.

Lessig failed in his attempt to fight the Sonny Bono Copyright Term Extension Act in the U.S. Supreme Court—the act that will keep Mickey Mouse out of the public domain for another 20 years. But despite this serious setback, Lessig has succeeded in convincing thousands of professionals to put their signatures on his so-called "Creative Commons" licenses, which allow colleagues and other professionals to freely cite from and reprint one another's work, and even make derivative works.

### Hardware Hacks

The problem here is that sharing may work for software, but it doesn't work for hardware. Moore's Law has driven much of the computer revolution, but it requires that companies like Intel spend more and more money each year to create the next generation of superfast chips. Take away Intel's copyright and patent protection, and knock-off companies would create clone Intel processors for a fraction of the cost. These chips would be dramatically cheaper than Intel's, and Intel would not have the money to create the next generation of still-faster devices. Moore's Law depends upon vectoral control.

Wark's opus doesn't just ignore hardware—it ignores hardware hacking, the tradition of modifying circuits and computers to do things that the original designers never intended. Hardware hackers are pros at both adding new features and removing arbitrary restrictions—like the region codes on DVD players that won't let European DVDs play in U.S. players. Yet increasingly, hardware is where the action is. Books such as *Hacking the Xbox: An Introduction to Reverse Engineering* are exposing secrets to the masses that once were strictly the province of MIT and Caltech midnight seminars. Hardware hackers are largely motivated by exactly the same antivectoralist tendencies as the hackers creating file-sharing networks: the desire to get around restrictions that have been artificially imposed upon their beloved technology. Hackers are people who use technical means to break restrictive rules and, as a result, create new possibilities. They are agents of disruptive change, no matter whether they hack code, networks, video-game consoles or copyright. By failing to address hardware and its hackers, Wark's work once again falls short of its title.

And what of information yearning to be free? The quotation comes from Stewart Brand, editor of the *Whole Earth Catalog*, speaking at the first Hacker's Conference back in 1984. According to a transcript of the conference printed in Brand's May 1985 issue, the full quotation was: "On the one hand information wants to be expensive, because it's so valuable. The right information in the right place just changes your life. On the other hand, information wants to be free, because the cost of getting it out is getting lower and lower all the time. So you have these two fighting against each other."

If I might be so bold as to reëngineer Brand's quotation while looking through Wark's glasses, it's the hackers who want information to be free, and it's the vectoralists who want information to be expensive. Having known and admired Stallman for more than 20 years, I've long understood the concept of the hacker. Wark's contribution in his misnamed volume is the identification of the hacker's enemy, the vectoral class. It is a battle, I fear, that we cannot win. But it is one that must be fought. ■

*Simson Garfinkel is a researcher in the field of computer security. He is the author of* Database Nation: The Death of Privacy in the 21st Century *(2000). He is currently a doctoral candidate at MIT's Computer Science and Artificial Intelligence Laboratory.*

# The Password Is Fayleyure

## Today's password schemes are unworkable and offer little security for users.

**BY MICHAEL SCHRAGE**

PokeKey1...ou812$...twasbrillig!. All were favorite passwords of mine long ago. The first is the name of the puppy I briefly had as a child. The second was shamelessly lifted from a Van Halen album cover. The third, you'll recall, opens *Jabberwocky*. I must have typed each one hundreds of times.

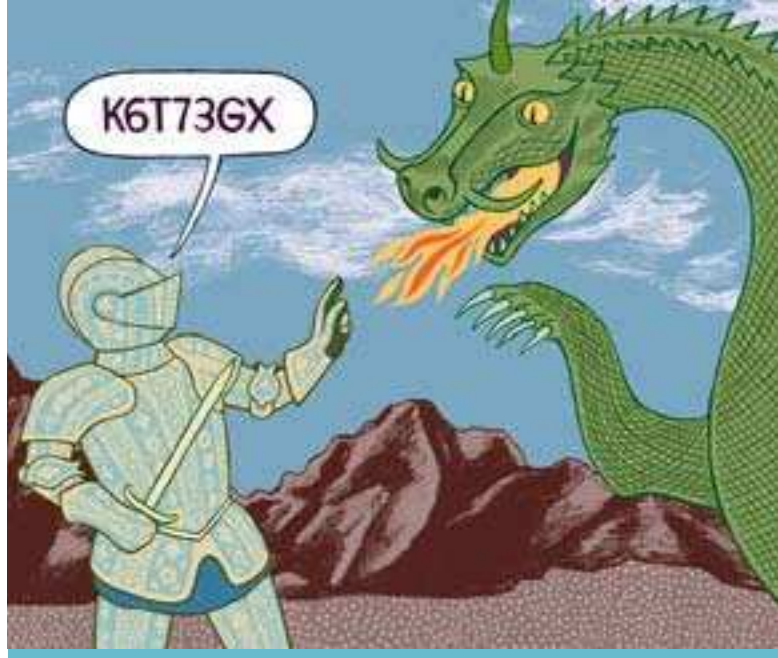
Looking back, I feel like an idiot for believing my wittily "unguessable" passwords enhanced my security in any meaningful way. Password protection is pervasive, annoying, inconvenient, and does little to deter anyone intent on doing harm. But you can't gain legitimate access to many services without it.

Yahoo Mail registration, for example, has come a long way from being an open invitation to spammers and spoofers. Who would argue that its automated "ID/password" reminders are not a boon for the lazy and aphasic among us? But Yahoo's relentless reliance on password protection is a security patch that feels more like a challenge to evildoers than a serious deterrent. And Yahoo Mail is among the better ones in a pretty bad lot.

Today's password authentication schemes are little more than security placebos. They perversely inspire abuse, misuse, and criminal mischief by deliberately making users the weakest link in the security chain. Greater teleprocessing power has made stealing or cracking password sequences ever faster, better, and cheaper. Security guru Mark Seiden observes that many hack attacks have nothing to do with how "strong" a target password is, because these attacks rely on brute-force discovery of alphanumeric sequences. "The bad guys are really attacking your keyboard," he says. That security system administrators make users jump repeatedly through digital hoops to defend the "integrity" of our four- to 12-character sequences falls somewhere between insult and joke.

If a company wanted to design a security system that made a mockery of everything we know about human behavior, cognitive psychology, and cryptographic analysis, it would come up with our contemporary bit-based babel of passwords. As authentication expert Richard E. Smith has observed, the logical conclusion of most "strong password" policies—don't use names of family member or pets; don't use birthdays or calendar dates; use randomized sequences of special characters; don't use your password for more than one or two sites; change your passwords several times a year; don't put your password(s) in your PDA or cell phone—is that passwords should be impossible to remember and should never be written down.

Somehow, the world's ATM banking systems have managed to get by with a bare minimum of fraud for more than 20 years by relying upon only four-digit codes. So what do the banking geeks grasp about password management?




Passwords that don't protect

**Under Review: Password selection for Yahoo! Mail, etc.**

The obvious answer: the stronger and more complex the password scheme, the lazier and more technically incompetent the security system administrator. As Smith demonstrates in a series of keen analyses, the rise of plain-text "sniffer" technology combined with computationally enhanced processing power makes traditional password protection ever weaker and more fragile.

So why are we demanding that millions of people spend more and more time and memory on a security procedure that yields less and less protection? The world doesn't need "better" or "more secure" passwords; it needs to wean itself from passwords and PINs as the medium of authentication. We'd be far more secure with more layered approaches to authentication—"suspicion engines" on the lookout for deviant behaviors—and more subtle yet persistent ways of tracking and challenging online identities.

The global silliness of the password mentality was beautifully highlighted in a survey conducted last year that found 70 percent of those asked said they would reveal their computer passwords for a bar of chocolate. Sweet. A third of those surveyed volunteered their passwords to interviewers without being offered a bribe. Yet another survey discovered that fully 79 percent of people questioned on the streets of London revealed such desirable security-sensitive data as mother's maiden name and birth date. "We are amazed at the level of ignorance from consumers on the need to protect their online identity," sniffed a spokesman for RSA, the pioneering encryption firm that sponsored the research.

Actually, I'm amazed by the laziness of global enterprises that make their users primarily responsible for the security and integrity of complex systems. If passwords are anywhere near as important to online authentication, identity, and security a decade hence as they are today, it will be the clearest possible signal that the virtual world has become an even more dangerous and volatile place for both transactions and interactions. ■

*Michael Schrage is a researcher and consultant on innovations economics and the author of* Serious Play *(2000).*

MICHAEL KUPPERMAN

# Synopses

**EDITED BY MONYA BAKER**

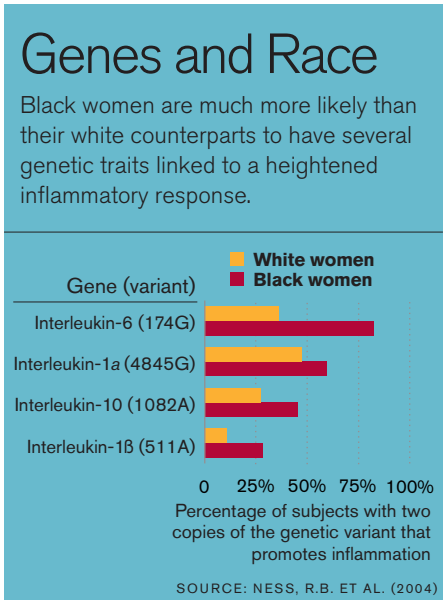
Each month brings new investigative tools, new ideas for revolutionary technology, and revolutionary applications of existing technology. No one can know today which will matter most tomorrow. But these represent *Technology Review*'s best prediction.

**BIOTECHNOLOGY**

## Inflammatory Genes

### Genes may put African Americans at higher risk of disease

**CONTEXT:** Heart disease, stroke, transplant rejection, and autoimmune diseases kill African Americans at a higher rate than white Americans. Access to health care, health behaviors, and socioeconomic and community factors explain many, but not all, of these disparities. Genetic differences are often discounted, because variations within a single racial group are larger than variations among racial groups and because race is increasingly viewed as a social construct rather than a biological one. Nonetheless, race-based medicine is hotly debated, and race-specific therapies are being studied. Many diseases that disproportionately afflict African Americans are linked to inflammation or an overactive immune system. To test whether genetics plays a role in these diseases, Roberta Ness and colleagues at the University of Pittsburgh tracked nearly 600 women to examine genetic variants known to promote inflammation.




**METHODS AND RESULTS:** The researchers tested for variants of six different genes among healthy women who received prenatal care before successful first births. Of these, 179 identified themselves as black, 387 as white. The genes coded for proteins, called cytokines, that regulate the immune system. For five of the six genes studied, black women were more likely than their white counterparts to carry a proinflammatory variant; the difference was statistically significant for four genes. For one gene, black subjects were 36.5 times more likely than whites to carry two copies of the proinflammatory variant. However, for any single gene, many white women carried a proinflammatory variant, and many black women did not.

**WHY IT MATTERS:** Improving unhealthy living conditions and habits and reducing social disparities will be most effective in preventing inflammatory disease; still, tests that show who is most likely to fall ill could help those at risk get preventive counseling and care. By demonstrating a genetic contribution to disease that is race-specific, this work suggests that race could be used as a shorthand for genetic predisposition to guide medical advice. This notion is controversial because of the high genetic variation within racial groups. Making decisions based on race alone will include some people who can't benefit from treatment and exclude others who can. To resolve this issue, genetic tests to assess risk factors should be developed. Meanwhile, using race as a kind of genetic proxy to inform preventive care might deliver the most good to the most people.

Source: Ness, R. B., et al. 2004. Differential distribution of allelic variants in cytokine genes among African Americans and white Americans. *American Journal of Epidemiology* 160:1033-1038.

## Insulin Version 2.0

### Fat secretes hormone that may control diabetes

**CONTEXT:** Abdominal fat is a dangerous thing. This is not because the fat clings to internal organs (which it does), but because it secretes a suite of hormones that preserve the fat's existence and affect metabolism. The result is an increased risk of a number of maladies, from diabetes to heart disease. In a series of experiments, researchers led by Iichiro Shimomura at

Osaka University found yet another hormone made by abdominal, or visceral, fat—one that, surprisingly, mimics the beneficial effects of insulin.

**METHODS AND RESULTS:** Using tissue samples taken from two human volunteers, Shimomura's team first identified genes that were active in visceral fat. The researchers tracked one of these genes to a protein known to help immune cells mature. Next, they studied more than a hundred people and found that the more visceral fat they had, the higher their blood levels of the protein. Another experiment observed mice genetically predisposed to obesity; as they got fatter, blood levels of the protein rose. Because the protein comes from visceral fat, the researchers named the protein "visfatin." Mice completely lacking the gene for visfatin died before birth; mice carrying only one functional copy of the gene had elevated glucose levels. Adding visfatin to liver, fat, and muscle cells had the same effect that insulin did; visfatin even lowered glucose levels in insulin-resistant mice. Still more studies indicated that insulin and visfatin bound to different spots on the same protein (the insulin receptor), which, when activated, causes cells to take in glucose. In fact, when the spot where insulin binds to its receptor was mutated such that insulin could not bind, visfatin still could bind, triggering the same response as insulin.

**WHY IT MATTERS:** Diabetes occurs when the body doesn't make enough insulin or doesn't respond properly to the hormone. The disease afflicts nearly 200 million people worldwide and is the sixth leading cause of death in the United States. This research opens another route to finding diabetes drugs. Either visfatin or molecules that fit visfatin's binding site could help control the disease. Teasing out the natural role of visfatin may yield insights; though greater amounts of fat produce greater amounts of visfatin, these levels are insufficient to counter the ill effects of obesity. Studies that resolve this paradox may show how obesity and its associated diseases could be prevented or treated.

Source: Fukuhara, A., et al. 2005. Visfatin: a protein secreted by visceral fat that mimics the effects of insulin. *Science* 307:426-430.

# Cholesterol Cure?

## Toward a plausible RNAi therapy

**CONTEXT:** RNA interference (RNAi)—once thought to be an experimental artifact, then considered an unimportant anomaly—is now recognized as an important technique for regulating gene expression in animals, plants, and fungi. In essence, RNAi occurs when small RNA molecules (short interfering RNA or siRNA) ambush messenger RNA, the molecule through which the instructions in a gene are translated into the protein that will act them out. At least three companies hope to transform the technology into new therapies. It's tough to do, because siRNA is rapidly destroyed in blood and has trouble getting into cells. Now, a team that is headed by Jürgen Soutschek and Hans-Peter Vornlocher at the biotech company Alnylam has shown that a new version of siRNA can travel through the bloodstream into cells and lower cholesterol levels.

**METHODS AND RESULTS:** Soutschek and colleagues made siRNA that would silence the gene for a cholesterol-boosting protein, apolipoprotein B. Using established techniques, they modified the chemical backbone of siRNA to make it more stable. In a novel approach, they linked siRNA to another molecule (ironically, cholesterol) that enters cells easily and injected the linked molecules into mice. The treatment lowered "bad" cholesterol levels by more than 40 percent, and follow-up tests showed that siRNA had entered cells and stopped production of apolipoprotein B.

**WHY IT MATTERS:** Drugs available today work in just a handful of ways. Most bind to a protein and affect its function. Others replace a protein. RNAi drugs would do something completely different: they would stop a protein from being made at all, and so treat diseases in ways that other techniques cannot. By showing that RNAi drugs can be delivered through blood, this research counters the strongest criticism of the technique. But more obstacles remain: in humans, siRNA must travel farther in the bloodstream than in mice, the amounts of drug required are still prohibitively high, and long-term treatments with cholesterol-linked siRNA may have side effects worse than the disease. Nonetheless, these results, and more like them, will begin to sway the skeptics.

Source: Soutschek, J., et al. 2004. Therapeutic silencing of an endogenous gene by systemic administration of modified siRNAs. *Nature* 432:173-178.

**INFORMATION TECHNOLOGY**

# Verbal Compass

## Better speech-based error correction for dictation tools

**CONTEXT:** Extreme multitasking is the modern fad, but no person has enough hands to manage a cell phone, a digital organizer, a steering wheel, and coffee all at the same time. Accordingly, people want a hands-free way to interact with computers. Although speech recognition systems are more accurate than ever, typical users still spend more time correcting errors than dictating text; half of their correction time is spent just moving a cursor to errors identified in, say, a dictated e-mail. "Confidence scores"—the software's estimates of how likely it is to have captured the right word—can be used to identify possible errors. Now Jinjuan Feng and Andrew Sears at the University of Maryland, Baltimore County, have shown that confidence scores can also be used to accelerate the correction process.

**METHODS AND RESULTS:** Twelve participants dictated 400-word documents using a speech recognition system. It interpreted 17 percent of the words incorrectly, a typical rate; it was the correction process that was atypical. The software used confidence scores to tag words throughout the text as "navigation anchors." Users could quickly jump to each anchor with short voice commands and then move a cursor word by word to the error. The researchers measured the number of navigation

commands the participants used, the failure rates of the navigation commands, and the time spent dictating and navigating. Average failure rates reported for other techniques are about 5 percent for direction-based navigation ("move right") and 10 to 20 percent for word-based navigation ("select December"). In a test of Feng and Sears's technique, the failure rate was only 3.2 percent. Even better, the time users spent navigating to errors was cut by nearly a fifth. This is significant compared with other error-correction techniques and it is promising, because this work suggests the means for further improvement.

**WHY IT MATTERS:** The Lilliputian buttons on PDAs and other pocket-sized wonders are quickly shrinking under a constant-sized thumb. Multitasking is on the rise, and more people with physical disabilities are entering the workforce. Both trends will steer users away from computer systems with manual interfaces. Speech recognition, but for its high error rate and long correction times, is an obvious alternative.

This work clearly shows that using confidence scores for navigation can shrink users' correction times. With further improvements, the technique promises to boost the usability of hands-free error correction and so engender a surge of new gadgets and applications.

Source: Feng, J., and A. Sears. 2004. Using confidence scores to improve hands-free speech based navigation in continuous dictation systems. *ACM Transactions on Computer-Human Interaction* 11:329-356.

# Quantum Corrections

## How to check errors in a quantum computer

**CONTEXT:** To an outsider, the logic of quantum computing can seem mystical. While a standard bit represents data as one way *or* another (digital 0 *or* 1), a quantum bit stores data as one way *and* another (0 *and* 1 and all possibilities in between). While a standard computer must crunch through possible solutions one at a time, a quantum computer could, in theory, survey all solutions at once and pick the correct one in a single step. This is ideal for solutions that rely on trial and error, such as breaking encryption codes.

But, like some cursed mythical creature, much of the information contained in a quantum system will vanish if it is observed, because the process of looking at it disturbs the system. That means a user can look at the answer to a question but can't check the calculations behind it. A quantum computer therefore needs to correct errors reliably without anyone actually seeing them. Now, for the first time, John Chiaverini and colleagues from the National Institute of Standards and Technology (NIST) have done this in a quantum system that could be scaled up.

**METHODS AND RESULTS:** In the NIST quantum computer, information is encoded in a single atom's quantum state. Using a process called entanglement, the fate of this "parent atom" is linked to that of two companion atoms, so that changes to the parent's condition are reflected in the companions. Using beryllium ions (atoms with electric charge) to carry quantum information, the researchers were able to disentangle, decode, and compare the states of the two companion ions and thus indirectly deduce whether an error had occurred. A laser pulse could then correct the original ion's quantum state without actually observing it.

**WHY IT MATTERS:** Many encryption techniques depend on the difficulty of factoring very large numbers through trial and error. A quantum computer could, in theory, defeat all such encryption systems and promises to be orders of magnitude more powerful than the most advanced systems today. So anyone interested in keeping digital secrets—from credit card numbers for Web transactions to classified information for governments and corporations—cares about quantum computing. Although a useful quantum computer is still far, far away, the work at NIST has shown how to lift one of the most bedeviling curses of quantum mechanics.

Source: Chiaverini, J., et al. 2004. Realization of quantum error correction. *Nature* 432:602-605.

# Scanning Your Thoughts

## Machines learn to analyze brain activity

**CONTEXT:** Can computers learn to read the human mind? Detecting thoughts may be beyond their abilities, but computers can be trained to recognize certain mental tasks from scans that monitor brain activity. One popular scanning technique, functional magnetic resonance imaging (fMRI), already aids the study of learning, memory, emotion, neural disorders, and psychiatric drugs. Using statistics and data analysis, researchers can identify patterns of activity as characteristic of certain mental activities and states. Now, Tom Mitchell and his colleagues at Carnegie Mellon University have shown that computers can automate this process, at least for some simple tasks.

**METHODS AND RESULTS:** Using fMRI data from subjects engaged in various tasks, the CMU team trained computers to recognize which fMRI patterns accompanied cognitive states for different tasks. During this process, the computer developed mathematical models to distinguish between different cognitive states. Then, given new fMRI data, the computers predicted the subjects' mental states from the brain scans. Though imperfect, the automatically trained computers convincingly outperformed chance in discriminating whether a subject was looking at sentences or pictures, reading ambiguous or non-ambiguous sentences, and reading words associated with different categories such as people, tools, or fruit.

**WHY IT MATTERS:** This work shows that a computer can use the results from one set of brain scans to predict what a brain was doing during other scans. This capability could eventually lead to more accurate use of MRI scans in medicine. It might also speed up data analysis, particularly when one individual is being studied over time. And, since the computers learned to recognize brain activity from a single short

interval rather than a composite of several scans over a longer time period, it might reduce the time each patient spends in an MRI machine, making expensive equipment more readily available.

More broadly, this work is an important application in the field of machine learning. With relatively few training examples, the computers were able to detect meaningful patterns in data containing thousands of inputs, many of them irrelevant or inaccurate. As scientists collect ever more detailed data sets from the brain and other complex systems, these techniques proffer a way to use the information more effectively.

Source: Mitchell, T. M., et al. 2004. Learning to decode cognitive states from brain images. *Machine Learning* 57:145-175.

NANOTECHNOLOGY

# Better Hydrogen Storage

## Nanosponge works on molecular level

**CONTEXT:** Hydrogen may be the fuel of the future, but major hurdles prevent it from being as versatile as oil. Storing hydrogen is one problem, particularly for cars and mobile devices; pressurized hydrogen gas must be stored in thick-walled tanks and so requires far more space than its energy equivalent in gasoline. Alternative-energy researchers have sought materials that could act as sponges, soaking the hydrogen in and holding it until it is needed, but no material so far has had the necessary hydrogen capacity at convenient temperatures and pressures.

Researchers from the University of Newcastle upon Tyne and the University of Liverpool have shaken up the hydrogen research community by discovering a new class of materials that addresses the problem at the molecular level.

**METHODS AND RESULTS:** The materials made by Xuebo Zhao and colleagues are composed of long carbon chains linked by metal atoms. When they are crystallized, these molecules frame cavities less than a nanometer across, connected by "windows" that are even smaller than a hydrogen molecule. While the cavities are being filled, hydrogen can wriggle through these windows because the carbon chains are flexible.

But once the cavities fill, the chains lose their room to flex, forcing the windows closed. As a result, the material can be loaded with hydrogen gas at high pressure, but does not release the gas when pressures drop to normal, essentially forming a molecule-sized pressure seal.

**WHY IT MATTERS:** Fuel cells running on hydrogen could be good for much more than cars; they could work in portable electronic devices such as laptops, handheld computers, and cell phones. While the materials made by Zhao and colleagues do not hold enough hydrogen for most commercial applications and only work far below room temperature, they open up an entirely new approach to hydrogen storage. With some amount of refinement, this nanoscale sponge could become a key part of a hydrogen economy.

Source: Zhao, X., et al. 2004. Hysteretic adsorption and desorption of hydrogen by nanoporous metal-organic frameworks. *Science* 306:1012-1015.

# Improving Your Memory

## A faster, cheaper, smaller way to make computers remember

**CONTEXT:** Which takes longer, walking to and from the coffeepot, or starting up a computer? The answer, sadly, is often the latter. That's because the most common computer memory technologies, DRAM and SRAM, are "volatile," meaning they require power to retain data and must reload information when restarted. Other memory technologies, such as the flash RAM found in today's digital cameras, cell phones, and PC cards, can hold data without power, but they read and write information too slowly to be used for computing purposes. Researchers at the University of California, Los Angeles, have recently designed a new form of fast, cheap memory, based on organic materials and nanoparticles, that seems to overcome many of these limitations.

**METHODS AND RESULTS:** A memory device is essentially a system that can switch between distinct states, like the "on" or "off" states of a transistor. Jianyong Ouyang and colleagues built a device from a thin film of material that switches between being more or less electrically conductive. They created a 50-nanometer-thick polymer film loaded with gold nanoparticles and an electron-rich carbon-based molecule, then sandwiched the film between two metal electrodes. When electrically grounded, the film can barely conduct a current. Apply enough voltage between the electrodes, however, and electrons move from carbon to gold, raising the conductivity through the sandwich by a factor of 10,000.

The transition occurs in less than 25 nanoseconds, the limit of what the team could detect; the states are stable even when the power is off and can be switched back and forth repeatedly. The polymer film is easy and cheap to make, and unlike silicon-based memory, these polymer-based devices could easily be built up in layers, enabling extremely high densities in a small volume.

**WHY IT MATTERS:** This research stands out from fierce competition because the cheap and simple methods reported yielded excellent performance, surpassing that of flash RAM and rivaling conventional computer memory.

But the streets of Silicon Valley are littered with the remains of engineers and investors who have tried and failed to break into the memory market. Ouyang and colleagues eventually must show that their memory device is reliable and can be manufactured on an industrial scale. Nonetheless, this new approach should be a contender in the battle for low-cost, high-density memory in digital cameras, cell phones, and personal computers.

Source: Ouyang , J., et al. 2004. Programmable polymer thin film and non-volatile memory device. *Nature Materials* 3:918-922.

# Executive Education for Technology Leaders

By Carol Hildebrand

The certainty of lightning-quick change is one of the few things CIOs can count on in the enterprise today. For most corporate IT executives, the past few years have only continued the nearly wholesale renovation of how businesses continue to communicate, innovate, and bring products to market. Global economies continue to adjust to the chaos and confusion of today's world, while the U.S. economy slowly marches back from a technology meltdown that began four years ago.

But in spite of the continuing uncertainty and chaos, the drumbeat of business goes on. "I think the greatest challenges that organizations face today is to figure out how to leverage ambiguity, paradox, and uncertainty to their competitive advantage," says Eric Fridman, director of marketing for executive education at The Kellogg School of Management at Northwestern University in Evanston, Ill. "Those factors are basic table stakes today, and you need to know how to grow the business in those kinds of conditions, not merely survive."

Technology is clearly the means to make this all happen, and CEOs expect their technology executives to fully grasp the importance of using technology as a tool for business innovation. Many CIOs are turning to executive education as the impetus for this necessary change.

## IT as lynchpin

According to *BusinessWeek*'s most recent special report on Executive Education, they do so with good reason. The magazine's survey on executive education found that the ability of executive education to help corporate executives develop the skills necessary to cope with the constantly changing array of workplace challenges is one of the top five reasons that companies send employees back to school. Small wonder that executive education programs have become so popular with CIOs.

"The competitive landscape has changed," says Rita McGlone, director of corporate programs for executive education at The Wharton School at the University of Pennsylvania in Philadelphia. "It used to be that technology was considered a cost-heavy area. Now businesses are really tightening budgets and looking for technology to actually add revenue rather than just costs."

This places CIOs squarely in the middle of some high-level and often conflicting mandates. How do you please the COO and CFO with a flatlining budget without gutting the IT investments so necessary to advance the CEO's business vision? Not only must CIOs successfully bridge this gap, they must do so while still building relationships and networks with a host of colleagues and external contacts, such as vendors, customers, and distributors.

## CIO as integrator

The bottom line? Just as CIOs concentrate on integrating technologies seamlessly together to allow vital business information to flow throughout an enterprise, so must they learn to integrate themselves into every function within a company.

"One of IT's true values is to be a service to other functions, and they need to know how those departments work so they can be ahead of the curve in adding programs," says McGlone.

But for CIOs to act as both visionaries and service-oriented functionaries, they must acquire a satchel of new skills to suit the ever-evolving nature of their positions. IT executives that rely on skills that have served them well in the past are not only missing the point, they may be missing the boat: Success lies in their ability to adapt and evolve in a role that cannot survive on stasis. All this adds up to an urgent need for fresh thinking about the problems and challenges of managing technology.

For Ethan Hanabury, the numbers tell the tale. Hanabury, associate dean for executive education at the Columbia Business School in New York City, says that he's seen a sharp rise in the number of technology executives attending the school's executive education program, particularly the four-week senior executive program, a general management development program with a focus on strategy and leadership.

"In the last two years, we've had 12 CIOs or equivalent titles in the program. That's as many in the past two years as we've had in the previous seven years," he says.

"One of the reasons I think there's a particular need for technology executives to attend executive education courses is that their role changes so much as business changes, and they need to be constantly up-to-date as to the latest business practices," says Hanabury. "They really are linking a lot of functional areas in an organization, and so it's important to go back and learn things like how strategy is made, what's good leadership, and effective ways to work in teams."

## Hot topics

Education experts cite the following course topics as generally popular with IT attendees this past year, but of particular relevance to CIOs:

**General business management.** As the CIO role is increasingly recognized as vital to corporate success, many are enrolling at general management programs such as the Senior Executive program at Columbia, or Harvard Business School's Advanced Management Program. "Our most recent sessions all had CIOs in them," says Hanabury. "I think companies are realizing that they shouldn't be thinking of CIOs within a narrow box, and that [CIOs] really need to understand the whole business." It also helps CIOs who want to step into general management roles make the leap to the business side, he says. "Many are being groomed for a higher role in the organization at some point."

**Leadership.** A successful CIO must learn to deal not only with the fluidity inherent in technology, but the unanticipated consequences of decisions made in an environment characterized by constant change. "All this adds up to a new notion of leadership," says Kellogg's Fridman. "It leads to the idea of a leader less as a heroic figure, and more as an architect of organizations and a teacher."

For CIOs to act as both visionaries and service-oriented functionaries, they must acquire a satchel of new skills to suit the ever-evolving nature of their positions.

Deb Giffen, director of executive programs at Wharton, says she's seeing a fair amount of CIO interest in their leadership programs such as "Leading Organizational Change" and "Building Relationships That Work."

"They're looking for effective leadership skills that help them influence new strategies and build relationships that work—both internally and externally, with vendors and suppliers," says Giffen.

**Strategy.** Schools like MIT's Sloan School of Management in Cambridge, Mass., and Stanford's Graduate School of Business in Berkeley, Calif., have crafted strategy programs aimed specifically at the CIO. For example, in Stanford's "Strategic Use of Infomation Technology" program, CIOs concentrate on how to best use technology to support business goals. "It's very much management of technology for strategic purposes," says Hau Lee, the Thoma professor of operations, information, and technology at Stanford's Graduate School of Business. The curriculum is nontechnical and emphasizes frameworks for maximizing the value of an organization's existing information technology assets, as well as using information systems to reshape organizational strategy and culture.

**Negotiation.** As CIOs continue the job of weaving technology into the fabric of business goals and processes, they must also become trusted partners of the business people who will ultimately use the technology and drive the business forward. Using an autocratic style won't work; instead, CIOs must learn the art of negotiation, says Hanabury. "CIOs need to have really strong team-building skills, because they have to be very effective at influencing large groups of people without having authority," he says.

Negotiation skills can be learned in open enrollment programs, but customized classes tailored for a specific company are also very popular. MIT's Sloan School of Management recently ran a custom program in which it paired IT staff with the businesses they sup-

port. "For them, it was about negotiation, and it was important to have the two sides present," says Marie Eiter, executive director of the MIT Sloan Office of Executive Education.

## Turnabout is fair play

While successfully embedding technology cleanly into the business world is undoubtedly a huge task for CIOs, the fact is that they'll need help from the business side of the house to get the job done. Recognizing this, many schools are including a dose of strategic IT thinking for functional managers in their classes, too.

Stanford offers an executive education course on global supply chain management targeted at business execs such as vice presidents of manufacturing or operations. Intentionally built into the program is a heavy emphasis on strategic use of technology. "It's very much a two-way street," says Lee. "These people also need to think about technology—you need an integrated meshing of the two." In fact, the course often has a CIO as guest speaker.

Wharton does something similar with a course designed to help CFOs cope with the rapid changes in business. "We bring in a CIO or former CIO to educate [the CFOs] on how to work with the CIO, and get better investment value from their IT investments," says McGlone.

Another change is in the duration of classes—time continues to be a commodity in short supply—so executive education programs have responded by adding shorter programs to their traditional mix. Kellogg's executive education group, for example, has put together a one-day program on creating a culture of innovation. "One of the things that we are hearing from executives is that they are so time-constrained that it's hard to get away for three to five days," says Fridman, who plans to offer an entire group of one-day programs.

Executive education programs require commitment—both an investment of time and money. But as the business world is characterized by a nearly dizzying rate of change, CIOs need all the tools they can get to help them operate effectively in the present and grow into the future. In such an environment, learning new skills could make the difference between a fulfilling career and treading water.

*Carol Hildebrand is a freelance writer based in Wellesley, Mass.*

# The Technology Budget Creep

**TECHNOLOGY PRODUCTS HAVE** become a big part of consumers' lives—and their bills. Of course, there are a lot more technology products to choose from now than in decades past, but the prices of many of those products have dropped drastically over the years. *Technology Review* set out to discover what the net impact of these factors has been on America's pocketbook.

The Consumer Price Index database is the only data source available that tracks the prices of all household expenditures over a long period of time. But because a certain number of technology products were only added to the survey in the 1990s, the earliest year with household budget data available on a broad variety of technology products is 1995. And the most recent information of this kind comes from 2002.

One interesting challenge that arose was the question of how to define a "technology product." While it might be argued that a soybean is as technologically derived as any new wireless handset, we included only product categories that depend on high-technology research and development: consumer electronics, computers, telecommunications, and pharmaceuticals.

Our analysis found that from 1995 to 2002, technology products gained 9 percent in their share of U.S. household expenditures. Computer products and cellular services witnessed the biggest increases in spending. Every year, U.S. households now fork over an average of $1,200 for consumer electronics, $1,868 for prescription drugs, and nearly $1,000 for telephone services. MARYANN JONES THOMPSON

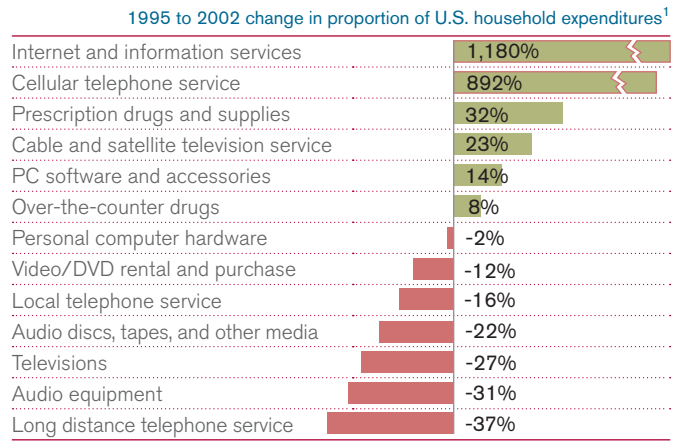
## Overall technology spending trend

Increases in spending on computers and pharmaceuticals offset decreases for consumer electronics and telephone services.

| | Proportion of U.S. household expenditures[1] | | |
|---|---|---|---|
| | 1995 | 2002 | Percent change |
| Total | 5.56% | 6.04% | 9% |
| Pharmaceutical products | 1.09% | 1.37% | 26% |
| Consumer electronics products and services | 1.76% | 1.74% | -2% |
| Telephone services | 2.36% | 2.32% | -2% |
| Computer products and services | 0.35% | 0.61% | 74% |

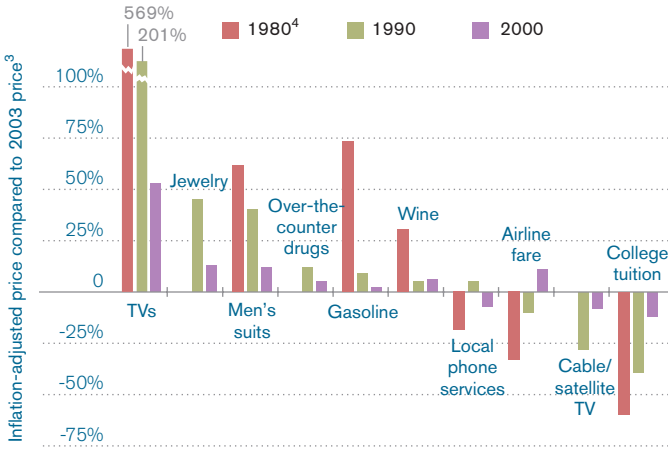
## Technology product spending trend

Spending on Internet services grew nearly 12-fold, to .25 percent of household income—more than is spent on newspapers and magazines.



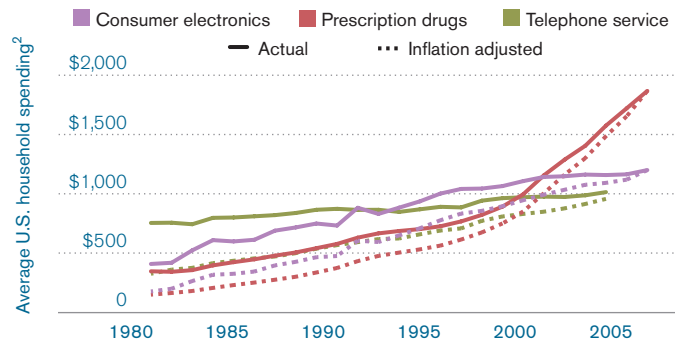

## Historical product prices compared to 2003

This chart compares what things cost in past years to what they cost in 2003, adjusting for inflation. In 1980, for instance, televisions cost 569 percent more than they did in 2003.




## Technology product spending history

In 1980, Americans spent more on telephone service than they did on prescription drugs. Today, the opposite is true.




[1] DATA FOR 1995 WAS GATHERED BETWEEN 1993 AND 1995 AND RELEASED IN 1997. DATA FOR 2002 WAS GATHERED IN 2001 AND 2002 AND RELEASED IN 2003. SOURCE: TECHNOLOGY REVIEW, BASED ON CONSUMER PRICE INDEX DATA, BUREAU OF LABOR STATISTICS. [2] PRICES ADJUSTED FOR INFLATION TO 2004 DOLLARS. PRESCRIPTION DRUG ESTIMATES FOR 2003 AND 2004 ARE PROJECTIONS. PRESCRIPTION DRUG SPENDING ESTIMATE FOR 2004 BASED ON 2003 HOUSEHOLD COUNT. SOURCE: TECHNOLOGY REVIEW, BASED ON DATA FROM CONSUMER ELECTRONICS ASSOCIATION, CENTERS FOR MEDICARE AND MEDICAID, FCC, AND BUREAU OF LABOR STATISTICS. [3] PRICES ADJUSTED FOR INFLATION TO 2003 DOLLARS. SOURCE: TECHNOLOGY REVIEW, BASED ON CONSUMER PRICE INDEX DATA, BUREAU OF LABOR STATISTICS. [4] WHERE AVAILABLE.

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# A Portraitist of the Earth

## Arthur Robinson merged science and art to overcome one of mapmaking's greatest challenges

**BY ANDREW P. MADDEN**

Arthur Robinson, the cartographer and geographer best known for his elegant solution to a mapmaking conundrum, died last October 10 at the age of 89. He merged a sense of aesthetic clarity with the mathematical rigor of science to reimagine the Mercator projection, a method for representing the round earth on a flat surface that had prevailed for the better part of four centuries.

In 1569, the Flemish cartographer Gerardus Mercator created a map of the world on a flat surface, as opposed to a globe. Such a map would be particularly useful for sailors. In doing so, however, Mercator encountered a challenge that was as old as the craft of mapmaking itself: how can a curved surface be accurately represented on a flat plane?

Mercator's solution was workmanlike, and relied mostly on mathematical considerations rather than aesthetic ones. In the end, his equations enabled cartographers to produce charts from which sailors could readily navigate. However, the visual distortions created by Mercator's projection were a source of consternation for mapmakers and aesthetes alike: following his method, Greenland appeared to be larger than South America, when, in fact, it is roughly the size of Mexico.

During a 1989 interview with the Chicago *Tribune*, Arthur Robinson explained the challenge in this way: "Take an orange and draw something on it, say, a human face. Now carefully remove the peel, trying to keep it in one piece, and flatten it against your kitchen table. You'll see that in making a two-dimensional object out of a round one, something has to give. Either the face gets distorted and looks all 'mushed out,' or in flattening the peel, it breaks into segments, dividing the face as well into several parts. A cartographer chooses between a series of those kind of lesser-of-two-evils alternatives."

In 1963, under commission from the map company Rand McNally, Robinson developed his own projection, a task to which he brought an artist's sensibility. He began by sketching a map that in both shape and size appeared to more accurately represent the world than Mercator's method did. He calculated a mathematical representation for this map later. The end result was a visual depiction of the world that had less distortion near the poles. The Robinson projection was used by Rand McNally in a number of its atlases and was also selected by the National Geographic Society as its primary world map. It is still in wide use today, though other competing projections have been introduced over the last 40 years.

For Robinson, as for his predecessor Mercator, mapmaking consisted of much more than equations. Rather, Robinson maintained that cartography was an essential form of intellectual and symbolic expression. In one of his textbooks, *Early Thematic Mapping in the History of Cartography*, he wrote, "The act of mapping was as profound as the invention of a number system.... The combination of the reduction of reality and the construction of an analogical space is an attainment in abstract thinking of a very high order indeed...."

Robinson began drawing maps for geography textbooks while conducting graduate studies at the University of Wisconsin. In 1941, he was recruited by the United States' Office of Strategic Services (OSS), predecessor to the Central Intelligence Agency, to work in its map division. Over the course of World War II, as the need for accurate maps arose, Robinson became chief of the map division for the OSS, overseeing at least 50 professional cartographers and developing nearly 5,000 maps for the war effort.

In 1945, Robinson was appointed to the faculty of the Department of Geography at the University of Wisconsin. Over the next 35 years, he established the preëminent program of its kind at Wisconsin, teaching courses in cartography and physical geography until his retirement in 1980. According to one history of American cartography, it was during this period that Robinson "established himself as the unofficial 'Dean' of American academic cartographers."

In addition to his status as an educator and the elevation of cartography in American universities, a big part of Robinson's legacy will likely be his emphasis on the inherent visual beauty of maps. As Robinson liked to point out, mapmaking is often considered "the oldest of the graphic arts," and in his estimation, an elegant map should always "be considered as worthy of wall space as a painting." ■

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*Technology Review* (ISSN 1099-274X), Reg. U.S. Patent Office, is published monthly by the Massachusetts Institute of Technology. Entire contents ©2005. The editors seek diverse views, and authors' opinions do not represent the official policies of their institutions or those of MIT. Printed by Brown Printing Company, Waseca, MN. Periodicals postage paid at Boston, MA, and additional mailing offices. Postmaster: send address changes to *Technology Review*, Subscription Services Dept., PO Box 420005, Palm Coast, FL 32142, or via the Internet at www.technologyreview.com/customerservice/. Basic subscription rates: $34 per year, Canadian residents add $10, other foreign countries add $30. Publication Mail Agreement Number 40621028. Send undeliverable Canadian copies to PO Box 1051 Fort Erie, ON L2A 6C7. Printed in U.S.A. ABC audited

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